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AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS.

NEW YORK, January 23, 1903.

The 172d meeting was held this date at 12 West 31st Street.

President Charles F. Scott called the meeting to order at 8:20 P.M. and said that the Secretary had an announcement to make.

SECRETARY POPE:—At the meeting of the Board of Directors this afternoon, the following 111 Associates were elected:

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TAYLOR, EDWARD R., Manufacturing Chemist, Penn Yan, N. Y.	N. S. Keith. C. C. Chesney. L. B. Stillwell.
WALLACE, ROSS STRAWN, Supt. Peoria Gas & Elec. Co., Peoria, Ill.	H. C. Eddy. Ervin Dryer. James Lyman.
WARDLAW, FRANCIS ANDREW, Electrical Engineer, R. W. Hunt & Co., Pittsburg, Pa.	H. F. Sanville. W. G. Whitmore. M. P. Ryder.
WARNER, RICHARD FRANCHOT, Electrical Engineer, General Electric Co.; residence, 17 Washington Ave., Schenectady, N. Y.	W. J. Davis, Jr. Chas. P. Steinmetz A. H. Armstrong.
WAYNE, JACOB LLOYD, 3D, Engineer in charge Installation, the New York Telephone Co., 18 Cortlandt St., New York City; residence, 142 Henry St., Brooklyn, N. Y.	J. J. Carty. J. C. Rennard. Wm. L. Puffer.
WELLMAN, SAMUEL THOMAS, Prest. The Wellman-Seaver-Morgan Eng'g Co., New England Bldg., Cleveland, Ohio.	Jesse M. Smith. N. H. Heft. T. C. Martin.

WELZ, FRANK,	Electrical Engineer, 53 West 128th St., New York City.	W. J. Hammer. Dr. Ernst Voit. C. F. de Nordvall.
WURSTER, FREDERICK WILLIAM, JR.,	Student, Polytechnic Institute; residence, 170 Rodney St., Brooklyn, N. Y.	Samuel Sheldon. Sydney W. Ashe. R.W.Hutchinson. Jr.
WYMAN, WALTER S.,	Manager, Messalonskee Elec. Co., and Oakland Elec. Co., Waterville, Maine.	Norman Ross. Ralph Sweetland. D. R. Bullen.
VALENTINE, WALTER SCOTT,	Asst. Engr., Westinghouse Church Kerr & Co., 8 Bridge St., New York City; residence, 258 Adelphi St., Brooklyn, N. Y.	S. S. Edwards. W. N. Smith. Geo. L. Hoxie.

Total, 111.

And the following Associates were transferred to Membership:

Recommended by Board of Examiners, Dec. 12, 1902.

LE ROY W. STANTON, Consulting Telephone Engineer, Cleveland, O.

MAX OSTERBERG, Consulting Engineer and Electrical Expert, 11 Broadway, New York City.

WILLARD S. ATKINSON, Electrical Engineer and Factory Manager, Zindars & Hunt, 127 Fifth Ave., New York City.

There will be a meeting of the Boston members in that city, at the rooms of the Massachusetts Institute of Technology, or in that neighborhood, on February 13th, as noted in the January Announcement. A small party of gentlemen from New York will go over on that occasion. Professor Elihu Thomson will preside at the meeting, and it is expected to be an occasion of considerable interest. If any of the members can make it convenient to go over from New York to attend that meeting they will please communicate with the Secretary. No printed announcement will be made in regard to this matter; it is entirely unofficial.

A paper read at the 172d Meeting of the American Institute of Electrical Engineers, New York, January, 23, 1903.

THE TELEPHONE SWITCHBOARD.

INTRODUCTION BY PRESIDENT SCOTT.

Imagination is outdone by invention. The inventor and the engineer accomplish more than the weird story-teller or the far-seeing prophet can portray. For centuries conditions have been imagined or a future pictured in which men were endowed with superhuman attributes. Ancient mythology made the swift-winged Mercury the messenger of the gods. Fairies have been given magical powers and charms, and there have been legends of seven-league boots; but all the flights of imagination, at least until electricity came to its aid, are transcended by the evolution of the telephone during the past quarter century. What would have been thought of a young man fifty years ago had he predicted that the time would come when he at his office desk or at his home, could in a moment's time be in conversation with any one of a thousand or of ten thousand or of a hundred thousand or of three-quarters of a million people in his own city or scattered anywhere within a thousand miles in city, town, hamlet or country. The thing has become so common that it has ceased to be a wonder or a marvel. But it underlies modern existence. It is a part of our business method, our commercial system, our social life. It has modified and modernized our methods, it has enormously accelerated the rate at which men can do work. The communication between the home and the store, the home and the office, the communication from office to office, the communications between the departments of a large organization and between office and store and factory—in fact, almost every species of communication, which formerly required hours or days of time expended for personal travel and for interview, or for letter-writing—all these things have been revolutionized by the evolution of the telephone. High-speed tools are modernizing the machine-shop—increasing output and reducing cost; the

telephone is the high-speed tool of the commercial world—it facilitates organization and coöperation, it increases output by doubling the work a man can do. It is one of the essential conditions of the increasing and enlarging activity of the present years.

The telephone is not merely an invention. The elements are the work of the inventor, but the great system of conductors and connections are more properly the work of the engineer—of him who applies the scientific discoveries of the inventor and embodies them into useful apparatus in an operative system. We may discard the marvel by which the voice through the infinitesimal current is reproduced at a far distant place and consider simply the mechanical apparatus by which the simple transmitters, receivers and conductors are combined into one great interchangeable flexible system. What are the means by which the wires from my telephone may in a moment be connected to the wires of any one of a hundred thousand telephones at the same moment that a thousand others are being connected in the same great system? Here it is that the work of the mechanical designer and the engineer have supplemented that of the inventor. Here it is that we see how the minutest details must be specialized and elaborated to bring the work of the inventor to the service of the people. True, there is the magic of electricity, but there has been also most elaborated scientific investigation coupled with the most exacting mechanical design in order to produce great results.

The telephone switchboard has not sprung into existence fully equipped for its requirements. It has been an evolution. The requirements themselves have been an evolution; an evolution in a field quite apart from that in which dynamos and motors and electric lighting and power transmission have held sway. The telephone evolution may have attracted less attention; it has been less heralded, and the details and methods are less generally known. The apparatus and the methods used in the modern telephone system have not come as the result of inspiration or luck, but they have followed along the lines of scientific evolution. The advance has been step by step, but the steps have followed rapidly, and in a score of years a system has been evolved, almost perfect in its operation, of colossal extent and marvelous in detail. It has brought about in these few years changes in our social and commercial methods greater than have occurred throughout centuries in the past.

A paper read at the 172nd Meeting of the American Institute of Electrical Engineers New York, January 23, 1903.

THE EVOLUTION OF THE TELEPHONE SWITCHBOARD.

BY THOMAS D. LOCKWOOD.

A historic account of the development of the telephone exchange, and an analysis of the mechanical and electrical features of telephone switchboard apparatus from 1877 to date.

Two poets, as far apart chronologically as Lucretius and W. S. Gilbert, have sung the praises of the magnet; and the muse of Cowper has not disdained to celebrate such homespun and ordinary household gods as the sofa and the timepiece, and though the telephone switchboard is not a prominently manifested effect of a great force of nature, and not even a household god, it is in such close alliance with more than one of nature's forces, and stands in such faithful attendance to some of our home divinities, that it well merits more attention from the chronicler than it has thus far received.

The highly organized and highly specialized collocation of apparatus that we now term the telephone switchboard, and which is at present employed in the large central stations of our great city exchanges, such as the Cortlandt street central station in New York, and the main central station in Boston, as a means of carrying out the varied and complex functions required at the central station end of a great number of telephone circuits, has doubtless been seen by, and is familiar to many of you; while probably many more have a speaking acquaintance with it, and have considered it with more or less attention.

Its present condition of relative perfection and high efficiency has, however, been attained only after persistent effort, and after many previous attempts, each in its result showing some progress, but each indicating or developing faults and errors to be overcome by its successor.

At the outset of the telephone exchange business every telephone man had to learn his trade. Even the telephone itself

was but two years old, and except Professor Bell and his immediate associates no one knew anything worth mentioning about that instrument or its capabilities. None certainly could foresee what direction the lines of improvement would take; and none could foreshadow the extent of growth which might be expected for such systems.

But notwithstanding the general ignorance, the telephone exchange came into existence; and with it necessarily came something for the convenient connection and disconnection of lines. It would be profitless to devote much time to the earliest switchboards of all. It is enough to say that during what I may call the dark ages of exchange telephony, the switching appliances were of three different types; and this largely because in the beginning there were three different classes of incipient telephone engineers. The electrical expert coming into the telephone exchange from the ordinary or regular telegraphic systems, naturally pinned his faith to the standard pin switchboard usually employed by the telegraph companies. Those coming from special systems such as the stock quotation printing, burglar alarm and district messenger companies as a rule exhibited a preference for a switchboard whereon the lines had brass terminal plates with plug holes in them, the same to be united by switch-cords armed at both ends with plugs to be inserted in these holes. The telephone men with no previous telegraphic experience of any kind, chiefly those who had grown up round Professor Bell, and under the influence of his immediate associates, were inclined to eclecticism as regards the rival claims to merit, of pin and cord switchboards; but believed in dividing the work of interconnecting and its sub-operations between two or more operators, of whom one set received calls and made the required connections on the switchboard proper; while the others acting in some sort as dry nurses to the subscribers, supervised the communication, sent outgoing calls and encouraged the subscribers to talk.

As a means of receiving calls, some of the pioneer switchboards had a row of electric bells mounted along the top of the board, one for each line, and in such cases there was a normally connected battery, supplying current to a group of lines, the bells being operated by break keys at the substation. Still others had closed circuit annunciators, one for each line, these also being operated by breaking the circuit. Soon, however, the battery was discarded, being superseded by magneto generators at the substations, and then of course open circuit annunciators were

substituted at the central stations. It is of interest to note that the battery, discarded twenty years ago as a cumbersome adjunct, is now one of the most cherished features of central station practice; and all through the history of telephone practice, thus it has proved, that appliances and methods discarded as being inferior at certain stages, have been revived under the stimulus of more favorable conditions and advanced knowledge, and have turned out to be useful in the highest degree.

Before 1880, it had become decidedly manifest that some kind of telephone exchange service must be provided during the night. Few exchanges could afford to keep regular operators constantly at work later than ten o'clock. Consequently, a compromise measure was resorted to, and a night operator was stationed in the central office with permission to sleep; and a night alarm consisting of a loud sounding vibrating bell was provided, connected in a local circuit extending in one direction to a bar constituting a stop on which all annunciator drops might fall, and in the other direction to all of the several drops; so that the operation of any annunciator would ring the bell and awaken the operator. This contrivance is still employed in many small exchanges, and enables exchanges to remain operative at night, while as yet the number of subscribers is so small that a night attendant could not be otherwise afforded. Before this date it was also discovered that while the Western Union pin switchboard unmodified might be a satisfactory switchboard for telegraph offices, it was decidedly unsatisfactory for a telephone exchange. It was slow; it was not easily manipulated; it did not easily lend itself to coöperation with the other exchange apparatus; and it occupied considerable space. In brief, it had been devised for the needs of a telegraph office where a switchboard is but an incidental device arranged mainly to facilitate the connection of any particular line with any particular instrument or battery; and only on rare occasions to connect one line with another. In telephonic work, however, the function of the exchange is the interconnection of one line with another at all times and nothing else. To paraphrase the well-known couplet of Byron, the switchboard is in the telegraph office a thing apart; it is of the telephone exchange the whole existence.

Summarizing these considerations, it may be truly said that the main difference between the telephone exchange switchboard and that of the telegraph office, or any preceding system, was that whereas the manipulation of the telegraphic switchboard

involves the employment of experts, the telephonic switchboard is so designed that it may readily be operated with great celerity by persons who are not only inexpert, but who actually are entirely ignorant of the nature of the operations which they continually perform.

In 1880 the most representative exchanges had switchboards employing long brass or painted connection strips extending from end to end of the board. In New York as elsewhere, switchboards possessing this feature were employed, but there the preferred switchboard was operated by cordless plugs; the cross strips having a number of plug-holes, while a series of vertical conductors representing the subscribers' lines crossed these horizontal strips at a right angle in the rear of the board, these being spring plates overlapping the holes. Thus, when the plug was inserted in the hole of the cross-strip, it made a good rubbing connection with the spring line strip behind. The cross strips were arranged in pairs and were connected by looping wires to an adjacent table fitted with an operator's telephone and a call generator where connections were supervised, and any two lines concerned in a connection were attached by separate plugs to the two strips of a pair respectively.

In other cities the long brass strips were employed without any vertical line strips, each line being represented by a single spring-jack only. When such was the case the connection could not be effected by simple plug connectors; but necessitated the employment of cords fitted at one end with flat wedges to enter the spring-jacks, and at the other with plugs to enter the holes in the crossing strips. In this case, also, the crossing strips were looped to tables where the connections were supervised by operators.

In these systems an incoming call announced itself by the fall of an annunciator. One of a number of switchmen (so-called) provided with a magneto telephone connected with a loop-plug adapted to fit the spring-jack of the calling line, would plug in and receive the order. The same switchman then united the calling line and the line wanted, to the two cross-strips of some particular pair; and thus connected them not only with one another, but also to the table of some particular operator. The operator notified of the connection thus made, would first send a call current from a generator to the subscriber wanted, and receive his answer orally, and would then unite the two lines through a disconnecting drop. It was usually a matter of diffi-

culty to get the two subscribers to talk with one another, and the operator had, as it were, to coax them along.

An early appearing difficulty with this class of switchboard was, that the connecting strips running as they did from end to end of the switchboard took up an amount of space entirely disproportionate to their usefulness. Accordingly, they were later severed at one or more places, so that a number of connecting strips on the same horizontal plane might be severally connected to the same or different operators' tables.

Although the pin switchboard unmodified had not proved itself to be desirable, a new form of it was evolved during the year 1880, which considerably prolonged its lease of life. It was in desk form with a vertical part behind the desk, and in it the lines were represented by corrugated strips of brass mounted on edge, and crossed without touching, by a number of other corrugated brass strips also mounted on edge; the connections of any two line strips with any one or two cross strips being made by sheet brass connection plugs adapted for insertion at the intersections.

This switchboard was arranged in a number of groups, each to be presided over by a single operator, performing all of the several functions in the connection of lines; and several cross strips were assigned to her for local connections, while a certain number of others were extended to each of the other sections. An attempt about this time was made to classify lines by the trades, professions or vocations of the subscribers, but this failed by reason of the fact that it turned out that very few subscribers cared to communicate with others in the same business.

One horizontal strip of each group was connected with an earth branch including the telephones of the operator of such group, and another such strip was in like manner connected with the magneto generator of the same operator. Thus, by inserting a connection plug at the intersection of any line plate with the operator's telephone or generator cross strip, and performing any other requisite operation, the operator might converse with the subscriber, or send a call.

This switchboard was of low initial cost, and was, therefore, suited to the times, for it had already been discerned that the income of a telephone exchange was not by any means all profit. It was, however, mechanically and electrically bad. It occupied considerable space and the electrical connections made by its plugs were imperfect. There is, indeed, a legend than an electrical engineer was visiting a certain central station, where this

switchboard was exhibited with pride, and asked whether the plugs made good connections. When assured that they did, it is said that he blew at the switchboard with the result that some forty or fifty of the plugs were blown out of place.

Meanwhile it had dawned upon a number of the telephone men of the day that the separate call generator at each switchboard adapted for manipulation by the operator, might be profitably superseded by a common generator supplying the entire central station, and having branches to each operator's position, and keys whereby the current might be transmitted over any line at will. This sometimes, and especially where power could not conveniently be applied, took the form of a calling battery supplemented by an automatic electro-magnetic pole-changer; but was preferably an alternating current magneto-electric generator, driven by any suitable power.

It will be seen that up to this time, indeed up to about 1884, there was no uniformity in switchboard apparatus; and there was no standard switchboard.

It had been ascertained by experience that the function of the central station was not merely to connect and disconnect telephone lines. It was far more complex. Calls were to be received, and signal receiving appliances therefore were to be provided. Calls were to be answered and orders received, and for this purpose means were requisite to connect the operators' telephones with a call-originating line. Before connection could be established between a calling and a wanted line, it was essential to ascertain whether such wanted line might not be already engaged, and for this ready means of communication between the operators was necessary. If occupied, the fact had to be reported to the call originator. If not, a call signal had to be sent to the station wanted; and thus means for sending signals was also essential; and finally some device had to be rearranged for the indication and reception of ring-off signals.

Most of these appliances had of course been associated in a kind of haphazard fashion with switchboards from the beginning; but not until about this time, was any attempt made to incorporate them in the switch apparatus as a definite part thereof.

Upon the commercial introduction of the multiple switchboard, which, though invented as early as 1879, did not obtain general acceptance until about 1884 or 1885, it seemed that the time for organizing these several devices into a complete and self-contained machine had arrived.

The thought underlying this type of apparatus is that the entire switchboard shall be divided into sections of suitable magnitude, and that each telephone line entering the station shall pass to every section and be furnished at each with a switch socket, so that at each section any two of the entire number of lines may be united for through communication. As practically worked out, the call receiving indicators of the whole number of lines were divided between the sections; and thus it came about that the call of a subscriber is always answered at some one section, and that switch connections in response to such call and between the calling and the wanted line are always made at the section where the call has come in and been answered.

There is no truth, however, better established than this: that each radical advance in electrical apparatus involves and paves the way for a number of subsidiary devices. And so it was here. The very fact that all of the incoming substation lines were represented by switch-sockets, and were accessible at each of a plurality of switchboards or switchboard sections, rendered further invention imperative. It became absolutely necessary to provide some means whereby the operator at any one of the sections could quickly find out for herself whether a line called for, was or was not "busy." Accordingly, such means were devised. Without a "busy test" the multiple switchboard would be little better than a theory. Provided with a busy test system it becomes the practical basis of continued subsequent improvement.

Nearly all practical "busy test" arrangements provide that the insertion of a switch-plug into any one of the switch-sockets of any line at any switchboard shall bring about some electrical change which can be tested for, and detected at all of the other switch-sockets of the same line. If found to be present, the operator infers that such line is busy, but if when tested for, such change be not manifested, the line is free and may be switched.

Scores of "busy test" arrangements have been proposed; but few are really practical. In that which was associated with the earlier multiple switchboards, the socket frames of every line were represented on the face of the board by a metal ring surrounding the plug-hole; and all the metal rings of all of the sockets of each line were permanently united to one another by a wire running along at the back. The shank of the switch-plug was also wholly of metal, and when inserted in the socket of any line at any board it acted to establish a conductive connection

between the telephone line proper, and the conductor uniting the metal rings, thus grounding the latter, since the telephone line was grounded at the sub-station. A small battery was included in circuit with the operator's telephone at each section-operator's position, and keys were provided whereby the telephone might be looped into any one of the switch-cords, a number of which were placed at each position. Thus, to test at any section for the ground, cross, or other abnormal condition, which would indicate that a wanted line was engaged at some other section, it was merely necessary to touch the tip of the switch-plug to the metal ring (hence termed the "test ring") of the socket, which at such section represented the line called for. Should the wanted line be busy, a portion of the current of the small battery would pass by way of the test ring and the tip of the plug through the operator's receiver and produce a clicking sound therein; but if the

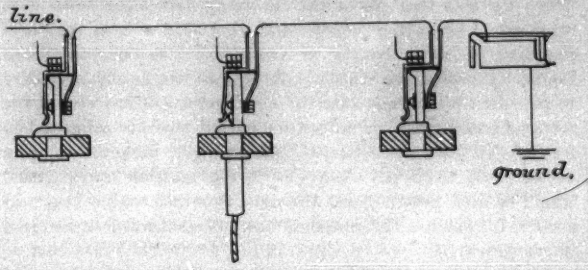

FIG. 1.

line when thus tried were disengaged, no such sound would be heard. In the multiple switchboard of that period, the jacks or sockets of the lines at each section were arranged in panels over the front of the board; the call devices were annunciators arranged in banks below these panels; the switch-cords with plugs at each end hung from a kind of gallows frame above; and on a keyboard in front of the operator were keys associated with the several switch-cords respectively, for directing the call current over any line switched to any particular cord, and for similarly connecting the operator's telephones in the circuit of any cord to answer calls, and to talk with either subscriber. The disconnecting annunciators, one for each switch-cord, were mounted on a single row at each section. The circuits were of the single wire type with earth return; the switch-sockets of the several lines—one for each line at each section—each had a spring and point

contact, and these contacts as indicated in Fig. 1, were all in series in the line.

As arranged for the switchboard of that period, the operators' telephones common to all cords of the section, were connected in an earth branch of the cord conductor; and the disconnecting annunciators, one for each switch-cord, were each connected directly in the circuit of its own cord. Fig. 2 indicates this arrangement.

Switchboards of this general type were installed for several years—the first one employed in New York being placed in a central office in John Street—and in general were clear improvements over everything preceding them; and among other features of advantage they greatly increased celerity in operation.

The disclosure, under operative conditions, of faults, weaknesses and opportunities for improvement was, however, inevit-

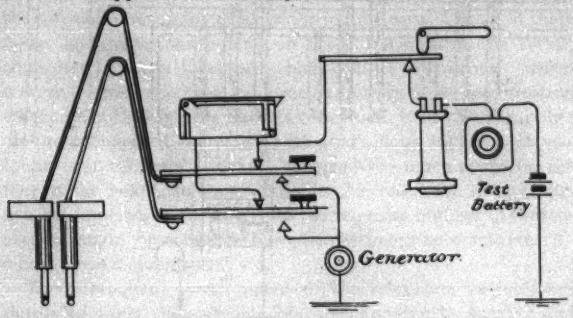

FIG. 2.

able, where the engineers of both manufacturer and user were constantly on the watch. It was very soon observed that the manipulation of switch-cords hanging from a point above, was a strain upon the operators, besides being in other respects inconvenient; and soon their position was changed, and the plugs were made to rest with the calling and listening keys on the keyboard, the cords hanging below with a weight for each, to keep it taut, and for its automatic retraction. Then it was noted that the speed of operation was restricted because on the receipt of a call signal, the jack of the line, the call of which was to be answered, had to be found in the panel where it and adjacent numbers were placed; and to the avoidance of this defect, the next improvement was directed. There was provided for each line at the section where its calls were answered, an additional

switch-socket to be used for the answering plug of a pair, and in responding to calls only. This was termed the "answering jack," and was placed close to the call signal of its own line. Switch connections were greatly facilitated by this expedient because whenever a call was received the operator was not required to take thought, but might at once plug into the answering jack which was close by.

After some four or five years' use of grounded circuit multiple switchboards it became evident that the time for the inductively neutral metallic circuit had arrived. One multiple board, the largest thus far constructed, had been set up and wired for grounded circuits; but so clearly was it seen that to proceed further in that direction would be a mistake, that this board was

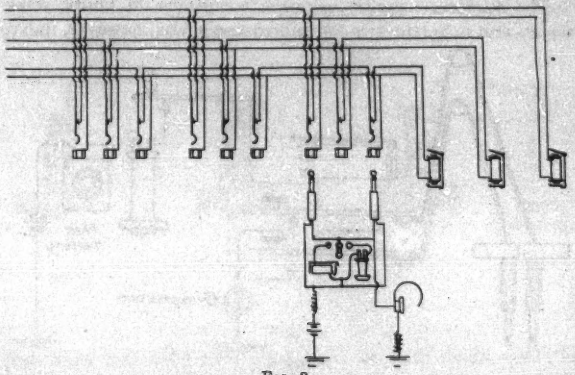

FIG. 3.

not put into operation until it had been completely re-wired for metallic circuits. This advance was a radical one, and followed the introduction of underground wires, almost as a matter of course. The series mode of arranging the spring-jack contacts was at this time retained, these being in one conductor, while the other main conductor was connected by parallel branches to the test rings of the circuit at the several sections respectively.

In this arrangement which is shown in Fig. 3, the call annunciator was connected on the answering-jack section between the two main conductors, the normal circuit through it being opened by the separation of the jack contacts when the switch-plug was inserted. This step in the onward progress of the switchboard carried one or two auxiliary improvements in its train. The

operators' telephones and clearing out annunciators were no longer connected alternatively in series in the cord conductors, but after a few tentative arrangements, were bridged between the cord strands, controlled, however, as before, by their several keys; but when thus placed, it became necessary to wind the disconnecting annunciator with many turns, and thereby give it a high resistance and impedance; as otherwise the voice currents from either of two circuits switched together, tended to be shunted through the bridged signal device.

The switchboard had now become a really good and homogeneous machine, well adapted to satisfy the conditions and requirements of its own day; and here for awhile its development seemed to be stayed. Yet it was soon seen that there was abundant scope for further advance. New switchboards became old, and old ones older. Others though still new were employed in the soft-coal consuming cities of the middle west. In all of these cases, and more particularly in those last-named, the series-connected jacks developed high-contact resistance which materially weakened the loudness and clearness of conversation transmitted through the circuits concerned; and as the number of lines connected increased with marvellous rapidity, it was found that the switch-sockets occupied too much space on the face of the board, so that a considerable reduction in size soon became imperative, in order that the requisite number of switch-sockets might be crowded, without detriment to operative efficiency, into a given space.

The subsequent development of the telephone switchboard depended upon the outcome of three apparently parallel and independent but really coördinate and gradually convergent lines of investigation, which were all about this time under consideration.

These investigations were directed towards:—

(*a*) The further improvement of the switchboard apparatus proper, by abolishing the serially-connected jack contacts, which as indicated, were a prolific cause of imperfect service; and by substituting some form of construction wherein each subscriber's line, when switched to another, would have a clear, continuous and highly conductive path through the switchboard for the voice currents; together with such other changes as each progressive advance might render necessary.

(*b*) To do away, if possible, with the multitudinous transmitter batteries of the sub-station and operating room, and to substitute

for them a common central source of transmitter current; for if this could be done, there would not only be effected a great reduction in the number of cells required, but such as were required might be kept at all times under the eye of skilled employees.

(*c*) To arrange if possible for the gradual displacement of the sub-station call generator, and the necessity for its operation in the transmission of incoming call signals; to provide that call and disconnect signals should be automatically transmitted by the simple acts of taking the receiver from the hook switch, and restoring it thereto; and to devise suitable appliances at the central station for the appropriate display of these signals.

These several directions of prospective advance seem superficially to have little necessary community with each other, but the closer they are viewed, the more apparent will it appear that the realization of all would inevitably involve the complete re-organization of the switchboard; and that the efforts thus far devoted to the subject must be regarded henceforth as having resulted mainly in the determination of the principles which should be followed; and of what features were and were not desirable in an ideal switchboard. This was a well advanced position; and constituted a definitive foundation on which the completely organized super-structure of an efficient modern switchboard might be successfully reared.

Considering first the direct improvement of the switchboard as a means for the rapid interconnection and satisfactory through operation of lines, it is sufficient to say with respect to the diminution in the size of the parts, that experience and practice had by this time enabled manufacturers to make spring-jack and other mechanism very small. The main problem was clearly the elimination of the serial spring-jack contacts. But how? Naturally, by arranging the switch-socket contact members at each section in parallel branches from both of the main conductors of their respective lines. But here was a difficulty: the serial spring-jack contacts were not by any means purposeless. The manifestation of incoming calls involved a subscriber's circuit, closed at the central office end, and an annunciator or similar call device connected in it; and the main purpose of the separable contacts in each jack was to ensure that while the spring member of such contacts which was on the lineward side should engage the inserted plug, the same should also be lifted by the plug tip from the fixed or insulated pin contact, thus opening the circuit at that

particular socket, and cutting off all that portion of the circuit inwardly; that is to say, the original terminal including all following switch-sockets, together with the annunciator. Herein lay the difficulty; for if the insertion of the plug merely made contact with two branch springs, and did not sever the main conductors, how should the original terminal and annunciator be cut off?

It is of interest to note that the connection of multiple board jacks in parallel was not at this time a new idea. Indeed, the multiple board as first devised was on this plan; but as then suggested, the difficulty outlined did not occur, since the board in question was intended for use in association with circuits over which incoming calls were not sent (there being a special call circuit), which circuits therefore did not have a central station annunciator, and might be, and were left normally open.

Every telephone engineer had known almost from the inception of the art, that electromagnets indiscriminately placed in series in a telephone circuit strongly opposed the passage of the rapidly changing voice currents, making reproduction of speech weak and indistinct; and by this time Oliver Heaviside had coined the word "impedance."

But if we take electromagnets out of the main conductors, they will of course no longer oppose the passage of the voice currents in their legitimate circuit, and if we then connect the magnets in bridge between the mains, we no longer need to disconnect them when we unite one line with another, because they still retain the impedance, which can be increased to any desirable extent, and because we can then make that impedance useful to prevent wastage of the voice currents through the bridges thus constituted. The disconnecting annunciator had, in fact, as we have already seen, been so connected; and on party lines there were many high impedance "bridging bells," so-called, also in parallel between the mains; which were employed without bringing about any perceptible depreciation of the transmitted speech. So then the first solution came to several minds at once. Why disconnect the calling annunciator at all? Why not disregard it, and leave it connected with the line while the circuit is switched, depending upon its impedance to prevent the short-circuiting of the currents through the annunciator branches thus left intact. This was done, but it became necessary as in the prior case of the disconnecting annunciator, to wind the magnets with many turns, and generally to make them of high impedance. There was, however, nothing objectionable in so

constructing them, because the higher the impedance, the less chance there was for the voice currents to be shunted that way.

Fig. 4 shows in diagram the talking circuit as thus formed between two sub-stations; the circuits of such sub-stations being switched together under these conditions. In this figure L and L^2 represent circuits extending from sub-stations s and s^2 respectively, to a central station c, and there provided with permanently connected call annunciators A and A^2. They are supposed to be united for conversation by the switch-cord conductors *c*, between which the disconnecting annunciator *d* is bridged. So connected, the line annunciators are obviously bridged also, and thus the through circuit has at the central station three bridges, each containing an electromagnet. Here, then, arises another difficulty. The wanted station must be called by the central station operator after the switch-plug is inserted in the proper line jack; and since the annunciator of the wanted line is not cut off, it will respond unless means are taken to prevent. Moreover, since it may be and probably is at another

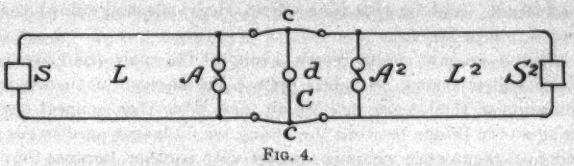

FIG. 4.

section of the board, its operation will doubtless be regarded as a call by the operator there, who of course will try to answer the supposed call. Again, when the conversation is over, and the sub-stations s and s^2 ring off, the line annunciators A and A^2 are again likely to respond, one of them in any event being probably at another section of the board, so that this also will be taken as an incoming call. A number of propositions looking to the avoidance of such false signals were proposed, but the most promising plan for the latter contingency was so to arrange the switch-plugs and sockets, that the insertion of the plug might close a local circuit containing an electromagnet, which magnet would when excited by the closure of its circuit, act to hold the armature of the annunciator in its normal position so that the annunciator could not operate and display its signal, even though a current should pass through its actuating magnet. This device, which is indicated by Fig. 5, worked in fact so satisfactorily that it not only prevented the undesired operation of the

annunciator, but also acted to re-set the same, when the signal had been given, pursuant to an original call; so that a drop fallen to display such signal did not need to be manually replaced, but was automatically restored as soon as a plug was inserted to answer the call.

In Figure 5, a represents the actuating and d the retaining magnet; h and h' are switch-sockets having line contact springs i and i', and contact rings k k' one behind the other, arranged to be conductively united on the insertion of the plug and through the metal shank thereof. The tip l of the plug makes

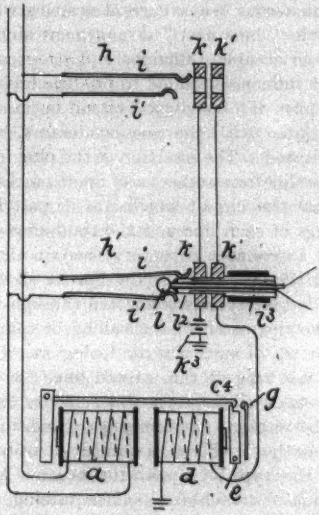

FIG. 5

contact with the shorter line spring i', the ring contact l^2 of the plug with the longer spring i, and the shank or sleeve l^3 with the two rings k k'. The inner rings k of each line are normally connected to each other, and to the grounded battery k^3; and the outer rings to each other, and to one end of the winding of the retaining magnet d, the other end of which is connected to ground.

A pivoted shutter of iron e is normally held by the armature catch c^4, and when released effects the display of the signal plate g. When the plug is inserted, the current of the battery k^3

excites the actuating magnet *d*, and this magnet attracts the iron shutter *e*, preventing the display of the signal, and withdrawing the said signal if it has been displayed.

In sending outgoing calls over the wanted line, a satisfactory expedient to prevent the operation of the annunciator of the line wanted, was so to connect the actuating and retaining magnets, that while incoming call currents passed through the actuating magnet only, outgoing call currents were passed through both actuating and retaining magnets.

So many adverse electrical influences were now abroad, by reason of the numerous heavy current systems which had been installed, that the " busy test " arrangement already described was no longer serviceable. Charges and stray currents on the line due to such influences tended to produce false busy signals. Accordingly, a form of " busy test " circuit never crossed or conductively associated with the line conductors, but altogether local was substituted. The insertion of the plug for the purpose of switching one line to another, was made to close one of two gaps in the local test circuit which was in part formed of the several test-rings of each line and the conductor uniting them; and also acted to connect a battery thereto, thus raising the potential of all the test rings of the line at all sections. The other pole of the battery was connected through the operator's telephone to the tips of all of the calling or companion plugs. Thus, when the tip of such a second plug was applied at any section to the test ring of the wanted line, the occurrence or non-occurrence of a click in the instrument, enabled one to readily infer the engaged or disengaged condition of the said wanted line. As thus modified, a number of switchboards were installed, and the type of apparatus became known as the " branch terminal " switchboard. The talking currents, had through this board a clear conductive path not liable to be impaired by the presence of jack contacts or other abnormal resistance; and in fact without any contacts other than those made at the actual switching points. Thus far, then, a desirable advance had been attained, and the branch terminal or parallel connection switch-socket arrangement has remained in use until the present time.

The branch terminal switchboard at first brought commercially to the front, did not provide for the other two desiderata which have been indicated. Yet these were not very far behind. It was more important to provide a central source for sub-station

transmitter supply common to all or a great number of lines, than it was to provide a similar arrangement for calls and other signals. But it seemed likely that if either could be practically arranged, the other might also be provided for by some modification of or addition to the same means; and in the end, thus it has turned out.

After much consideration and trials, both experimental and commercial, of many plans, the "how" of an efficient central and common battery system for telephone circuits, and the central and sub-station transmitters, together with a system of incoming call signals and supervisory signals was as a whole devised, and decided upon. In it, the same central office source of current may be employed for both signals and transmitters. The branch terminal mode of switch-socket connection was retained, each socket being composed of a frame-piece with a test ring in front, and two or more internal contact springs. At each section are the call devices, and the answering jack for the lines which are to be answered there, and a switch-socket for all lines entering the office; there being also a sufficiency of switch-cords, each with a switch-plug at each end.

The sub-station circuits were then arranged to be, while at rest, conductively closed at the central station through a battery and call device, and conductively open at the sub-station; but it was necessary to provide some kind of an operative circuit for the polarized sub-station bell, as otherwise calls from the central station could not be received; and the plan which seemed most promising, and which has been generally adopted, is to place a condenser between the severed ends of the two line conductors and in series with the bell magnet. By this expedient while the circuit is open at the sub-station for a steady current, it is practically closed for the passage of the alternating ringing currents of the central station generator, to which the bell is adapted to respond. There is also the ordinary hook-switch which serves as a support for the receiving telephone when not being used; and as long as the receiver remains in place on the hook, the foregoing conditions continue; but as soon as the receiver is lifted from the hook, the metallic circuit is closed through the sub-station telephones and the current of the central battery being thus enabled to flow, causes the operation at the central station of the call signal relay.

A small glow lamp serves as the line or call signal, possessing the great merit of being prompt and self-acting both in display

and withdrawal; and in practice is placed in a short local circuit controlled by the call signal relay, which has its magnet connected in the main line, and is responsive to the initial operation of the sub-station hook-switch.

Fig. 6 indicates the arrangement, which as regards the initial

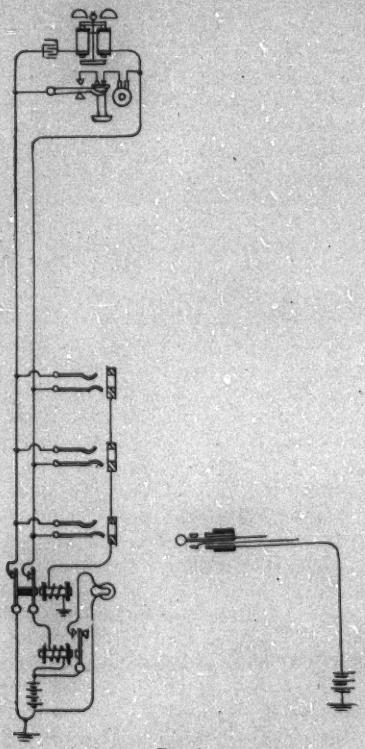

FIG. 6.

call signal was now complete; and also illustrates the devices now to be described.

The constantly connected annunciators of the branch terminal board were thus superseded by a relay and a lamp, and the appliances formerly employed to maintain the quiescence of such

annunciator were now made, instead, to operate a cut-off relay by means of which the lamp-operating relay might be cut away or disconnected, and the lamp signal thereby withdrawn, as soon as the call was answered by inserting the switch-plug. This cut-off relay has two resting contacts through which the two conductors of the main circuit respectively pass, in such manner that on the excitement of the relay and the consequent attraction of its armatures, the contacts are parted and the continuation of the line, including the call relay and the normal battery connection is cut off. The cut-off relay itself is in a local switchboard circuit controlled by, and leading through contact pieces of the switch-plug and socket. The switch-socket for this purpose has interior contact springs for both main conductors, thus leaving its frame-piece or test-ring at liberty for the local circuit; and the several test rings of each line are united by a fixed conductor extending from all of them to one terminal of the cut-off relay. The plug also has three insulated contact pieces adapted to register with the two line springs and the test ring of the socket; the cord conductor extending between each pair of plugs comprising two main line strands which extend from plug to plug, and a local circuit strand for each plug. A battery has one of its poles connected with the plug local circuit conductor and the other to the remaining relay terminal, so that when the plug is placed in the socket of any line, the cut-off relay circuit is closed, and the relay operates to disconnect the line terminal and relay. At the same time the potential of all of the united test rings of the line thus switched is raised to furnish appropriate conditions for the "busy test."

But this is not all. Supervisory signals are regarded as being necessary. These, also, are lamps, and two such are provided for each switch-cord, and associated with the two plugs respectively, being placed in the cord section of the local or cut-off relay circuit. Thus placed, they are, of course, non-operative except when the plug is in its socket; but the plug being thus inserted, their function is to afford an indication to the operator of the condition of things at the sub-station. They can only be displayed when the hook-switch at the sub-station is in its lower or normal position; that is to say, the position in which it is maintained while the receiver hangs on the hook. When in answer to a call the operator inserts the answering plug in the socket of a given line, the associated lamp does not light, because the sub-station receiver has already been taken from

the switch to give the order. But when the companion plug is placed in the socket of the wanted line, the lamp signal of that plug does light, because the receiver at the wanted sub-station is not removed from the hook; it thus follows that when this receiver is taken up in response to the call, the light is at once withdrawn. Again, when the conversation is over, the replacement of either or both sub-station receivers will once more illuminate the corresponding lamps to serve as a disconnecting signal. Or if either party desire at once a connection with some other line, the lamps may be made to flash several times in succession, by oscillating the hook switch. It must be apparent that such a system of supervisory signals is both ingenious and scientific. Its essential and underlying principle is that the supervisory signal of each plug is controlled in part by the plug and socket switch contacts of the local circuit wherein it is connected, and in part by the hook switch at the sub-station of the line to which the switch-socket belongs; and further, that the working of the signals is dependent in the first instance upon which of these two switch devices was first operated. Thus, in the case of a call being answered by the insertion of the switch-plug, the signal is not displayed because the corresponding hook switch has previously been operated; but in the case of a sub-station to be called, the supervisory signal is displayed because the plug and jack switch is the first to be operated, the hook switch in this case remaining unchanged until after the call is sent.

To enable the hook switch to control the signal, a low resistance relay is placed in the main circuit conductors of each plug, which relay being thus connected in the main line, is responsive to the closing and opening thereof as the hook switch is moved in one direction or the other.

The sketch Fig. 7 illustrates this arrangement, and shows that the relay in question does not act directly upon the local circuit of the lamp to open and close the same. This cannot be allowed because the same local circuit serves also for the operation of the cut-off relay and "busy test." It acts, however, by controlling a shunt round the lamp signal, closing the said shunt and preventing the display of the light when the main circuit is closed, and current consequently flows through the relay; and opening the shunt to permit the display of the lighted lamp when the receiver at the sub-station is replaced, causing the hook switch to open the main circuit so that current to excite the relay no longer flows.

In the figure, L L^2 are the sub-station circuits extending between the sub-stations S S^2 and the central station C, and adapted to be switched together for conversation at the latter. The switch-cord *c* has the battery B bridged between its main conductors, and has local circuit conductors for each plug, forming in association with the fixed conductor which unites the test rings, the local circuit; R R are the cut-off relays, R^2 R^2 the supervisory relays, *m m* the supervisory lamp signals and *h h* their controlling shunts.

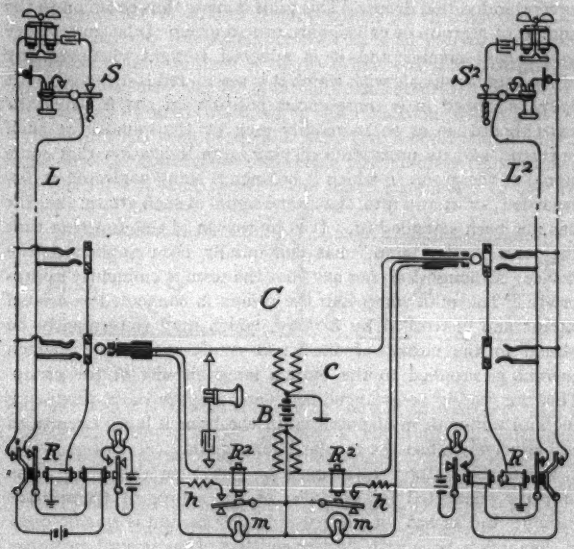

FIG. 7.

The battery which develops the current for the main line to excite the relay, is, as shown, preferably bridged between the two main circuit cord conductors, which respectively unite the tip and forward sleeve contacts of the two plugs, and so connected, divides the cord circuit into two well-defined sections looping from each plug. The same battery provided with an earth connection at one pole, may serve also to furnish current in the local circuit to illuminate the lamp signal, and indeed also for the operation of the cut-off relay and busy test appliances; the

several circuits being properly proportioned to the battery power and to one another by suitable resistances.

Another improvement tending to increased promptness of service in responding both to " call " and " disconnect " signals, is the " pilot lamp." This is an auxiliary luminous signal which may be advantageously associated with both of the foregoing classes of regular signal. It complements the regular signals much in the same way that a bell in a hotel or domestic annunciator system is made common to and complementary to the several individual drops. This pilot lamp is thus common to the signals of a group of call signals, or to a group of the supervisory switch-cord signals, and it is adapted to light whenever any of the regular signals with which it is associated is displayed. It may be placed in a conspicuous position on the front of the switchboard, so as to be readily seen by the monitor or chief operator, and its protracted display is an indication that some signal of the group to which it belongs is being neglected or disregarded; or at any rate, that some signal of such group, thus far has not been attended to. It is by reason of this function that the term " pilot lamp " has colloquially been applied to the device; although I do not say that the term is eminently appropriate. The pilot lamp like the others is connected in a local circuit and controlled by a relay, which may conveniently be placed in the circuit of the main conductor through which current is supplied to the branch lamp circuits of the group. This can readily be arranged in several ways without producing such an undue drop of potential in the branch lamp circuits as will adversely affect the regular lamp signals.

When the battery is bridged as has been described, it is properly connected for use also as the source of transmitter supply; and as has been suggested, may be and is so employed in connection, both with the transmitters of the several operators and those of the sub-stations. An important condition of success in the employment of a single battery for a large number of transmitters, is that its internal resistance shall be so low relatively to that of the circuits supplied, that the operation of any transmitter will not cause any material variation of potential at the battery terminals. When this condition is properly complied with, there will not be any interference between the circuits of the several transmitters; and such compliance is best attained by the employment of storage batteries. To further reduce the internal resistance of the battery and the chance of

interference, a plurality of banks of cells, each bank having a sufficient electromotive force for the work—say 24 volts—may be connected in parallel with each other.

But another condition equally essential in the operation of the sub-station transmitters of an exchange from a common battery, is that by means of the switchboard devices and in their normal operation, it shall be possible at any time to disestablish this universal state of reciprocal neutrality or non-interference as regards any two circuits, and so to segregate or set aside any pair or any number of pairs of circuits united for through communication, that the component circuits of such pair or pairs may freely communicate each with the other, but shall not disturb, or be disturbed by, any other circuits connected with the battery.

One plan of operation meeting this condition, which to a certain extent has been used, is to introduce a considerable impedance into the conductors connecting the main circuit strands of the switch-cord and thereby the main conductors of the two

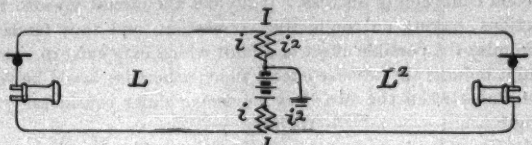

FIG. 8.

circuits concerned, with the pole or poles of the battery; and to establish a short-circuit, preferably containing a condenser, between the corresponding conductors of the two component circuits, and round the impedance. The steady current of the battery finds no further difficulty in flowing through the impedance devices than that due to simple resistance, and thus readily passes over the line in either direction to the sub-station transmitters, but cannot pass the condensers; while the voice currents developed by the action of the transmitters upon this steady current being in a state of constant and rapid fluctuation, are prevented from short-circuiting themselves through the battery bridge by the interposed impedance coils, but pass with great facility round these coils and through the path which includes the condenser to the distant station.

Fig. 8, however, illustrates an alternative plan which thus far has found more general acceptance. It consists in associating the two united sub-station circuits L L^2 and the common battery

B bridged at the central station between their main conductors, with an induction coil I of the type often styled repeating coils, wherein the two windings i i^2 have a like number of turns and like resistances. The two windings, as is clearly shown in the figure, are connected in the component circuits respectively, so that the circuits are in inductive relation with one another. Both windings are centrally divided, and the bridged battery unites the halves of both on one side to those on the other side of the circuit Each component circuit is thus supplied separately with battery current for the transmitter of its sub-station through its own winding of the induction coil; and each is alternately the transmitting and receiving circuit. The voice currents developed by each transmitter circulate in the transmitting component circuit only, but acting through the induction coil they develop substantially identical voice currents in the receiving circuit also, which passing through the same, operate the distant receiver. This arrangement well complies with the second condition of success. It divides the circuit up into two sections, having no conductive connection, and thus tends to minimize the possible effect of a fault which may exist in either; and it reduces the adverse effects which otherwise would be very noticeable when the two lines connected differ considerably in length.

In Fig. 9 is illustrated the application of this plan for central and common transmitter battery operation to the switchboard apparatus; and furthermore, represents in diagram the sub-station and switchboard connections of two circuits, showing how the same central source of current may be employed in connection with call signals, circuit control and speech transmission.

I may in conclusion briefly advert to a minor improvement which in some installations has been added with a view to further relieving the operator of the time-consuming duty of following up sub-operations. This is a device combined with the ringing key, which acts after the key has been manipulated, to lock it in the ringing position with the call generator connected to line for a definite and supposedly sufficient period of time, or until the attendant at the station called, responds by taking the receiver from the hook. One way of arranging such a device is to provide a spring latch which when the key is depressed engages a shoulder on the key spindle; to mount the spring upon an armature; and to associate with each key an electromagnet to act upon this

armature, the same being wound with but few turns of coarse wire, and connected in the key branch of the generator circuit. The key having been pressed, is thus held in operation, because the current of the generator through the circuit (which, before the

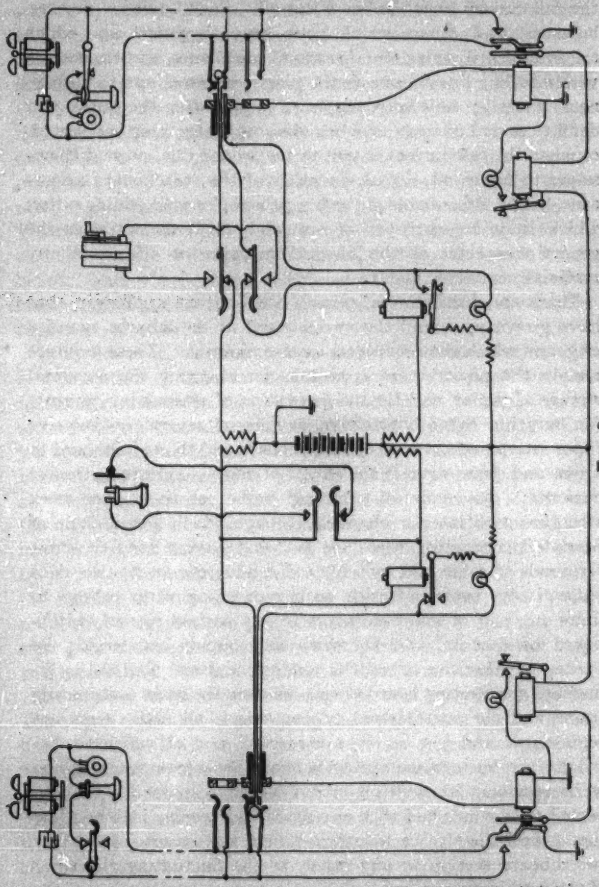

FIG. 9.

removal of the receiver from the hook at the sub-station is, as we have seen, kept conductively open by the inclusion therein of a condenser), does not excite the releasing magnets. But as soon

as the call is responded to by the removal of the receiver from the hook, the circuit is conductively closed; and the generator current now steady and strong, is sufficient to excite the magnet, which attracting the armature, acts to release the key; so that the call current over the line is cut off. Such auxiliary devices, however, and others which have been suggested and which are intended to bring the operators' telephones into connection with a calling line as soon as the plug is inserted, and to disconnect them by an electromagnetic switch after the lapse of a definite period of time, or when the companion plug is inserted, or when the call current is sent to the second line, present themselves to my mind, not as essentials of the switchboard apparatus, but as refinements of the lily painting or gold gilding order; which may be employed or not, and which do not alter the general character of the finished machine or effectuate any materially modified result.

There are, furthermore, certain concomitant appliances that have grown up round the switchboard as do suburbs round a city, and which should at least receive mention. These embrace mainly the power room apparatus for charging the universal storage batteries, and for the generation of alternating currents for outgoing calls; protective devices of several coöperative types interposed between the cable heads and the switchboard to arrest and guard against the effects of various harmful intrusive currents; the main distributing frame, an iron open-work structure with interior channels through which a multitude of insulated connecting wires are led, and having binding screw terminals of cable and switchboard conductors on its two sides respectively, between which such connecting wires extend to unite any pair of line conductors to any desired pair of switchboard conductors, and at which any circuit can readily be opened or otherwise altered for testing purposes; and the intermediate distributing board placed between the main distributing frame and the switchboard proper, where all main wires are represented and can be cross-connected, and at which to distribute the business equitably between the operators, any line while retaining its multiple switch-sockets can readily be connected or re-connected with any desired answering jack and line signal, and thereby be transferred in a few minutes from any switchboard section to any other, as the fluctuating character of the work may require.

While these appliances which in every large and well-appointed

central telephone station are now uniformly provided as accessories of the switchboard, cannot within the reasonable limits of this paper be discussed in detail, they are of course to be kept in mind in planning and preparing specifications for the central station apparatus generally and the switchboard in particular; and their proportionment, design and relation to the switchboard, with which they are to be associated, are matters which in each installation require the most careful and exhaustive consideration.

There is no great invention which has more thoroughly revolutionized business methods than the speaking telephone. The exceeding value of time is better appreciated now, than at any previous period in the world's history; and it is universally recognized that a business man's time is a business man's best asset Wherever the telephone is employed—and it may truly now be said that "there is no speech or language where their voice is not heard," and wherever the telephone exchange has obtained a footing, there at once is a valuable economy of this most valuable possession attained.

It is, however, obvious that to realize this conservation and economization of time to the fullest extent, the possibilities of usefulness inherent in the telephone itself must be competently seconded by a central station switchboard through which all of the several operations and sub-operations requisite for the connection and disconnection of lines, can be carried out with accuracy and celerity. The Standard Relay Switchboard—as the organization of apparatus and circuits whose development I have traced has been entitled—is such an instrumentality; and by it, notwithstanding the marvellous increase of late years in the number of lines entering large central stations, and in the number of calls received and connections made in pursuance of such calls, the speed and efficiency of operation has been not only well maintained, but has exhibited marked improvement.

Here, then, at least for the present, we take leave of our theme. The efforts expended in producing the switchboard which for the time is standard, are amply justified by the general satisfactoriness of its work. True, its organization is complex, but so is that of every poly-functional machine; and why should we object to complexity if accompanied by corresponding efficiency; or unless it shall be proved that the same efficiency can be achieved by simpler means.

This switchboard, though not yet a perfect product of evolution, is at least a complete and successful machine; but evolution

still goes on. It may well be that the next step in its never-ceasing progress will be in the direction of simplifying the organization either in its concrete devices or in its circuit arrangements, without any sacrifice of efficiency.

A paper presented at the 172nd Meeting of the American Institute of Electrical Engineers, at New York, January 23, 1903.

AN AUTOMATIC TELEPHONE OPERATOR.

BY WILLIAM J. HAMMER.

A description of an automatic telephone exchange operator, power driven, which performs the functions of switching, signalling, line-clearing, etc., of the human operator, and by exactly similar means. Also a comparison of the salient features of the manual and automatic systems.

For a considerable period of time the public mind has been steadily educated up to a high appreciation of, and great confidence in automatic time, energy, and money saving appliances. In the telephone field the subject of automatic telephone exchanges has been one which has attracted a great deal of attention ever since the original work in this direction of Messrs. M. D. and T. A. Connolly and T. J. McTighe, whose system the writer had the pleasure of examining as long ago as 1881, at the first electrical exhibition held in Paris.

The above system has been the basis of very many of the patents which have since been taken out on automatic telephone exchanges; and it is my privilege to-night to present for your consideration a radical departure in automatic exchanges which embodies a new principle of which it is the pioneer exponent. It is a most meritorious and ingenious piece of apparatus, and is termed the "mechanical operator," in contra-distinction to all other types of automatic exchanges, as it is the only invention which does the work of switching in a telephone exchange in exactly the same manner as by the human operator, and by exactly similar means. It is a light machine, and occupies comparatively little space. It is driven by power, and moves mechanically the equivalents of the ordinary plugs and cords in the usual switchboard, connecting the subscribers' terminals together when desired, signaling both parties, and disconnecting the same automatically when parties have finished speaking; and accomplishing this without necessitating any departures from the general arrangement of circuits met with in standard prac-

tice; and doing away with all but a fraction of the relays, magnets, electrical contacts and connections essential in all other systems, both manual and automatic.

The multiple system of telephone exchanges has now reached a very high degree of perfection; and it has become more and more costly; and it is well understood that as the number of subscribers connected to any manual or automatic exchange increases, the operating and maintenance expenses increase in far greater proportion than the number of subscribers, because of the increase in the number of multiples.

There is an urgent demand to-day for a system which will *very* materially cut down these *very heavy* expenses and cut off the *very heavy* outlay now necessary for operator's salaries.

Before entering into a description of the apparatus itself, it will perhaps be as well to consider just what the functions are which the human operator fulfils in connecting and disconnecting subscribers, and in what way the mechanical operator duplicates these functions; and I will, therefore, place them side by side:

Cycle of Operations.

The Automatic System.	Manual System.
1. The subscriber sets his sender to the number wanted, and winds it; this requires the turning of the discs and moving the lever, his responsibility ending there.	1. The subscriber takes the receiver off its hook.
	1a. Operator notes "pilot" light signal and individual signal light.
2. The exchange drops his (the subscriber's) terminal shuttle, which starts his sender going.	2. The operator places an answering plug in his jack upon seeing his signal displayed.
	3. Operator raises the listening key cam, which depresses the key, thus enabling her to communicate with the subscriber.
3. The sender sends a signal into the exchange selector, thereby establishing *one* of a hundred local circuits.	4. She asks "number" (this operation has no parallel in the automatic exchange, as the starting of sender is a natural consequence of the dropping of shuttle).
4. The exchange drops shuttle of subscriber wanted.	5. The subscriber gives the number wanted.
	6. The operator repeats the number to prevent error.
5. The motive power at exchange lifts both shuttles into an idle bus bar. (This operation has no parallel in manual working).	7. Operator must select "jack" wanted.
	8. Operator makes a busy test by tapping with tip of her plug

6. The ringing device rings bells of both subscribers.

7. The subscriber on hearing signal takes off his receiver. (This operation not in manual practice, as receiver there is off already).

the collar of the multiple jack of the line wanted.

9. The operator plugs the multiple jack of subscriber wanted.

10. Operator presses ringing key, thereby ringing up subscriber wanted.

11. Operator restores the listening key, cutting herself out.

12. Operator notes that subscriber's signal lamp goes out.

Next, conversation begins.

Upon its Termination.

8. Subscriber hangs up receiver.

9. Clearing-out magnets drop both shuttles back to rest.

13. Subscriber hangs up receiver.

14. Two keyboard signals light.

15. Operator removes both plugs of the pair from jacks.

This is the entire series of operations gone through in a "successful switch." Should, however, a busy line be called, then the following happens.

BUSY TEST.

THE AUTOMATIC SYSTEM.

1, 2, 3, same as above.

4. Operator attempts to drop called shuttle, but it is out of the way, and a special circuit is opened.

4a. Shuttle is for a moment hung up, but then clears out again.

(No further operations follow, as subscriber waits for bell, before taking down receiver).

MANUAL SYSTEM.

1, 2, 3, same as above.

4. Operator in multiple board taps the collar of the multiple jack of the line wanted, and she receives a series of "clicks" known as the busy test.

5. Operator tells calling party, line is busy.

6. Subscriber hangs up receiver.

7. Operator removes answering plug from calling subscriber's jack.

It will be noted from above that the number of operations necessary varies, and favors considerably the mechanical operating system, those requiring the subscriber's attention are less in the automatic, and he need not wait for the operator to question "number," and after receiving the same, repeating to prevent error and saves that time as well as the time often lost in getting the operator to understand the correct number etc.

Comparison of Apparatus Forming Salient Features of Both Systems.

The Automatic System.	Manual System.
1. Subscriber's instrument.	Same.
2. Sender.	Not in Manual.
3. Subscriber's line.	Same.
4. Protective devices, lightning arresters, heat coils, etc.	Same.
5. Subscriber's terminal carriage with contact springs and connecting rod.	This is represented in a manual exchange by subscriber's line jack.
6. Individual magnet.	This is equivalent in office to subscriber's drop or lamp signal, and its operating relay, cut-off relay, also puts line lamp out by cutting out line relay.
Above comprises the first group of exchange apparatus, and there are as many above items, as there are subscribers.	Same.
Automatic.	**Manual.**
Group 2.	
1. Bus bars.	Cords and Plugs.
2. Shuttle locks.	.....
3. Clearing-out magnets.	
The apparatus in this group is present in a number equal to 1/10th of the number of subscribers.	Clearing-out drops or supervision signals. Same.
Automatic.	**Manual.**
Group 3.	
1. Battery and leads therefrom, or dynamo.	Same.
2. Operating power.	These two items are represented by the operator, in a manual exchange.
3. Operating mechanism proper.	
The apparatus in this group is provided once only per section of 100 lines.	Same.

Description of the Automatic System and its Operation.

It is difficult to give a complete technical description of this system without recourse to many numbered drawings, diagrams, photographs, etc.; and those who are specially interested in this subject will find it of great service to witness the actual operation of the system itself, which may be seen at the present time in New York City.

This system comprises two separate devices: first, A "mechanical telephone operator," situated at the telephone exchange,

the original form of this being shown in Fig. 1; secondly, A "sender" or signaling apparatus, as shown in Fig. 2.

The "Sender."

Let us first consider the "sender" and its functions. It is preferably placed near each subscriber's telephone, and by its means each and every subscriber is enabled independently to control the mechanical operator at the central exchange. There is no mechanical connection of any kind between the subscriber's instruments and the "sender;" and it can be attached without cutting the circuit; it being only necessary to connect it in parallel across the existing line and to ground. The ground connection is only made for the switching act, when the instruments are idle, and during conversation they are free from ground.

The subscriber's "sender" or calling apparatus consists of a small metal box containing a set of disks, numbered on the periphery from 0 to 9—one comprising the units and the other the tens; and in the case of higher numbers being employed, additional disks are attached—three disks would give numbers up to 1,000; four disks would give numbers up to 10,000 and five disks up to 250,000. The number of the subscriber to be called is displayed in a line across the "sender" face, and a series of impulses corresponding to this number are sent over the line to the exchange by means of a clockwork started by turning the calling lever projecting from the front of the "sender." This lever upon being turned upwards winds the spring of the clockwork, it then returns to its first position, where it is locked, thus preventing further interference until the call has been sent and properly received at the central exchange. When the "sender" starts the varying series of impulses which are sent over both legs of the metallic circuit simultaneously, the ground (which has been automatically thrown on) is used for a return circuit. The "sender" also contains a magnet whose armature normally retains the clockwork until the magnet is energized by current from the exchange. As in the case of a messenger call or fire alarm box, the calling lever must be turned to its full extent to send a signal, and after this has been done, the protective devices in the "sender," as already stated, keep all the essential parts of the "sender" locked during the dispatch of the signal. When the switch is completed at the exchange, the subscriber, as well as the party whom he has called, receives a bell signal. There are four of these signals given to called subscribers, cover-

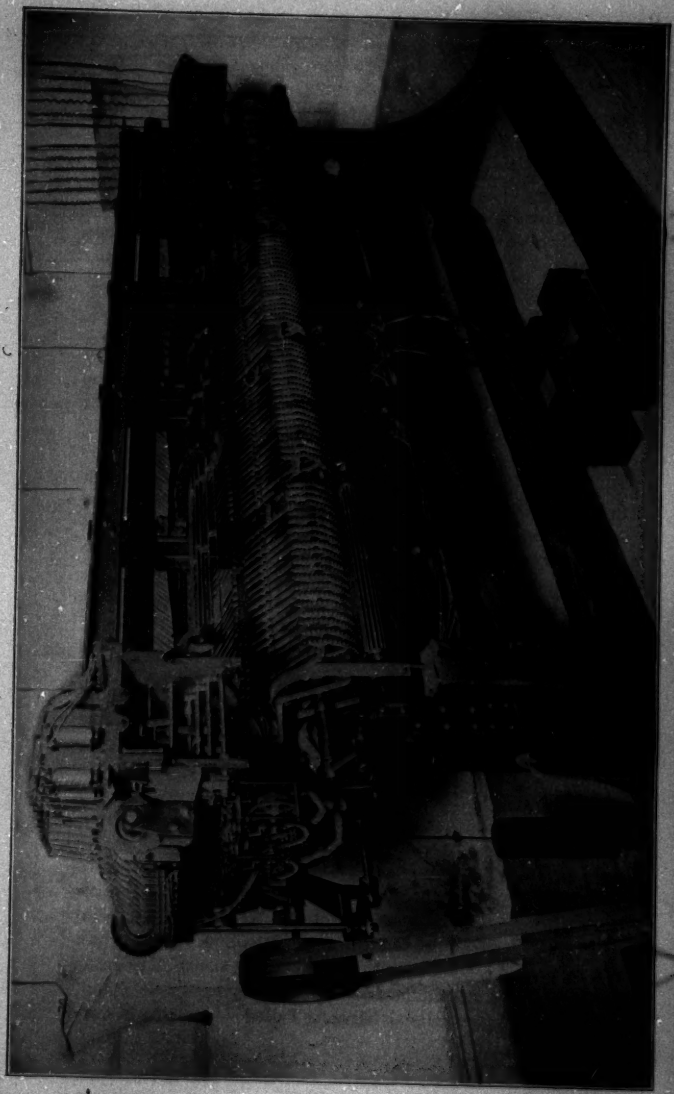

FIG. 1.—The Automatic Exchange Operator. (Original form.

ing a period of 30 seconds time; this period giving the called subscriber time to reach his telephone. As soon as he has taken off the receiver the signals cease and conversation begins.

The Mechanical Telephone Operator.

We will now consider the operator (shown in Fig. 1), and its functions:

All subscribers' circuits are normally free from ground and as already stated, the subscriber's calling device or "sender" is normally open, both as to ground and metallic circuit. In Fig. 3 is shown a diagram of the circuits.

Each subscriber's line terminates in one place only at the exchange—this being a feature not possessed by other automatic systems—each subscriber's line, consisting of two wires, is connected at the exchange to two parallel rods on the mechanical operator.

These rods are insulated from the rest of the machine, each pair supporting a carriage, mounted so as to slide on these rods.

This carriage holds the subscriber's terminal springs, which are insulated from each other, but each spring makes an electrical contact with one of the two rods.

The springs on the carriage are adapted to slide by, or at some particular point to make contact with one of a series of bars laid in a grill at right angles to and above the carriage rods.

All of the rods or bars employed in the machine are of such dimensions as to have practically no resistance, and the conducting bars and loop circuits connected with them containing impedance coils, and a source of electrical energy, such as a storage battery, and constitute the equivalent of the cord circuits of the manual exchange, and in their functions correspond identically therewith.

While the number of subscriber's terminal carriages is equal to the number of subscriber's lines, the number of cord circuits, or pairs of parallel bars necessary, need not be more than 10 per cent. of this number, this figure having been found safe in manual exchange practice. There are instances in which boards have had to be equipped with twelve and even sixteen cord circuits per 100 lines, but the average present multiple practice is from seven to ten.

It is never found that all subscribers wish to talk at one and the same time.

When the subscriber's line terminal switch or carriage at the

FIG. 2.—Subscriber's Instrument and Sender.

exchange is at a position of rest, one of the subscriber's line terminal springs makes a contact with the ground spring, which is connected to one of a circle of commutator pins. These pins are swept over by a revolving brush attached to the shaft of what is termed the "busy wheel" and which is normally in rotation. There are as many pins on the commutator as there are subscribers, and the revolving brush establishes a connection between a ground spring (subscriber's line) and a battery, operating magnet and ground.

The "busy wheel" to which the commutator brush is attached is driven by a friction clutch from a power device operated preferably by an electric motor, and is arranged to be stopped by a pawl and ratchet controlled by the operating magnet termed the "starting magnet," which initially controls the entire switching operation of the exchange. The energizing of the "starting magnet" stops the "busy wheel" and starts the operating gear, which passes through its complete cycle, after which the "busy wheel" is again started, continuing to revolve until the "starting magnet" is again energized.

A second magnet termed the "restarting" magnet is employed to start the master shaft going again; in order that the carriage-moving or cord-circuit operating device of the called subscriber may be thrown into gear.

These two "starting" and "restarting" magnets operate in conjunction with the subscriber's "sender" through the medium of a controlling contact apparatus and selector.

The commutator above referred to consists of two sets of circularly disposed contact pins, the number of the pins in each circle representing the number of subscribers.

There are also two metal contact rings, one of which is solid and the other divided into ten equal segments.

The rotating trailer arm attached to the "busy wheel" shaft sweeps over these contacts. The contact pins of one circle are each connected to a separate ground terminal spring; and one of the contact rings is connected in circuit with the "starting magnet," a battery and ground connection. The purpose of the *contact device* is to prevent any other subscriber from throwing the "starting magnet" into operation while switching is going on, the circuit in this "starting magnet" being always opened, save when the "master shaft" is at its point of rest. Each subscriber's line is brought into connection with the ground—once in each revolution, by the revolving contact arm.

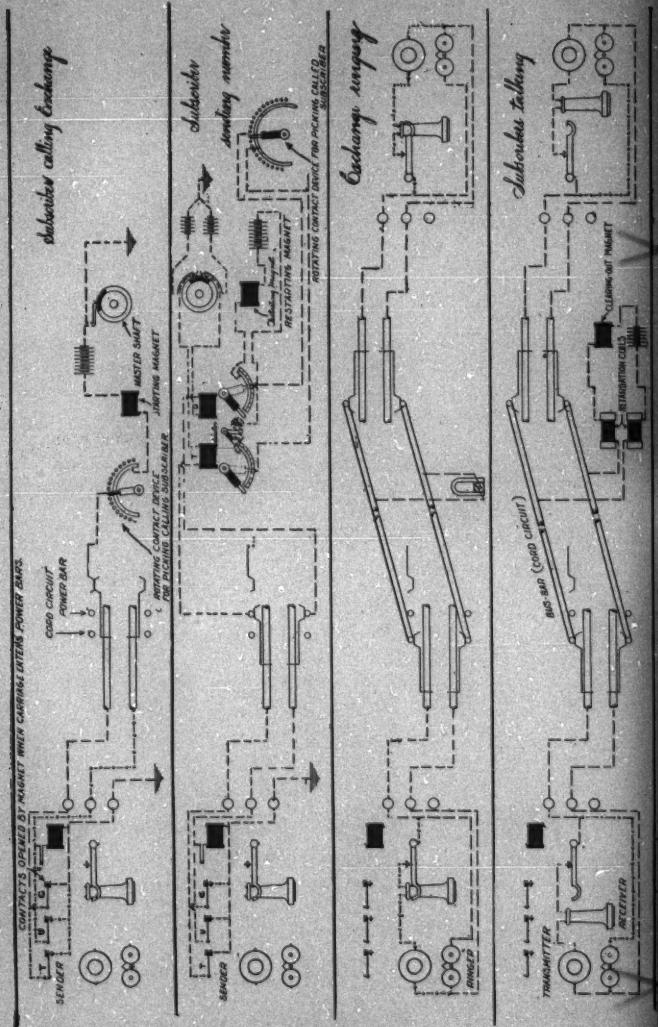

FIG 3.—Diagrams of Circuits.

All apparatus shown in solid lines. Wiring shown in dotted and broken lines. Broken lines show circuits closed. Dotted lines show circuits which are open.

The " busy wheel " which has been referred to, consists of a shaft extending through the entire length of the " mechanical operator," which carries mounted upon it and disposed around it in the form of a helix of a single turn, a series of resilient fingers of thin sheet steel, their number corresponding to the number of subscribers.

When the "busy wheel," which is normally running, has been stopped by an impulse sent through the " starting magnet," one of the steel fingers, which is always the one in a perpendicular position, remains resting against the latch holding that particular subscriber's terminal carriage. Next the power mechanism acting through a clutch and cam shoves forward a light shaft termed a " rack," which is studded with pins corresponding to the number of steel fingers and latches, and which runs parallel with the axle of the " busy wheel." As this " rack " moves longitudinally, the

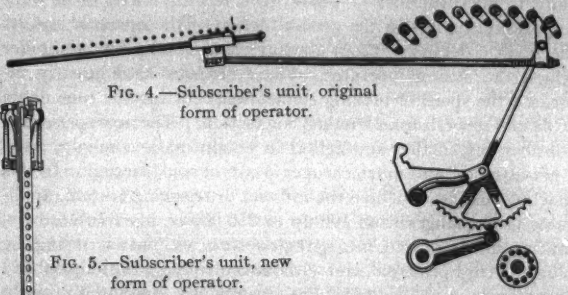

FIG. 4.—Subscriber's unit, original form of operator.

FIG. 5.—Subscriber's unit, new form of operator.

upright steel finger is bent over by a rack pin tripping the latch and thus releasing that subscriber's rod and shuttle, which drop into contact with a long lantern pinion; this pinion then rotates through an arc dependent upon the number of subscriber's lines busy at that time. Instantly a lever engages the two subscriber's shuttles, lifting them up so that their hook heads engage a shuttle detent. There are as many of these detents as there are talking circuits., *i.e.*, one-tenth the number of subscribers (in this machine the number being ten).

A circuit is now established between the springs of the subscriber's carriage and the grid bars representing the cord circuit terminals.

The magneto generator is now thrown on the circuit, ringing the bells of both calling and called subscribers. The length of this

signal may be varied to suit requirements and is controlled by a timing device. In the meantime the power mechanism has been automatically thrown out of operation and the " busy wheel " again rotates until another call is sent in.

When the subscriber takes his receiver off the hook a " clearing-out " magnet prevents the switch from clearing out; but when both receivers are hung up, the " clearing-out " magnet becomes de-energized, and its armature causes the shuttles connected to return to their position of rest.

Indirect or Trunking System.

Up to the present time we have considered the original type of the operator, as illustrated herein, and applicable to small exchanges up to 100 subscribers and employing the so-called direct connection, requiring a single machine accessible periodically to all subscribers. There have recently been made very important changes in the general design of the operator and its mechanical details, without altering the general principles under which the system operates. These changes have greatly increased the speed of making connections, cutting the time down to 3½ or 4 seconds for a trunked connection. The new operator is considerably smaller and lighter in weight, more compact, more " get-at-able," and much cheaper in cost of construction. In this machine also is embodied the indirect or trunking system, applicable to exchanges from 100 up to 250,000 or more subscribers, uniting all, if required, into a single system without sacrificing the plug and cord principle, and without multiplying the subscriber's contacts, as in all other systems, and finally, making it entirely practicable to sub-divide the lines into groups of 100, thus keeping the dimensions of the connecting machines within moderate limits.

The act of connecting subscribers, consists of three functions, each represented by an independent section of the operator. In the order in which these devices are thrown into use in establishing a connection, they are termed the " originator," the " pilot," and the " terminator."

The "originator" performs the office of establishing a connection of the calling subscriber's line with the " A " trunk. These " A " trunks are conductors connecting the " originator " and " pilot," and their number represents the maximum number of subscribers which would at any time be simultaneously using the section. It is well to note here that these " A " trunks always

have their beginning and ending in the " originator " and " pilot" of one and the same unit of 100. In this initial act of the " originator," no selective operation controlled from the subscriber's station takes place; but the " A " trunks which are already in use are made inaccessible to subsequent calls, the " originator " always selecting a free and idle " A " trunk. The end of the first free " A " trunk is connected in the " pilot," with a receiver or selector, which immediately upon the establishing of the connection between the " A " trunk and the subscriber's line receives a group-signal referred to later; and thereupon selects a " B " trunk corresponding to the signal received. Immediately the mechanism of the " pilot " connects the " A " trunk and the " B " trunk, at the same time breaking the connection between the " A " trunk and the selector, and putting the selector in connection with the next idle " A " trunk—the " B " trunks referred to connecting the " pilot " and the " terminator."

The ends of all of the " B " trunks, coming from one and the same section of 100, are distributed over all the " terminators " of the exchange, rendering it possible by the aid of one of these " B " trunks to establish a connection between the " pilot " and any one of the " terminators." Here again, as many " B " trunks are provided for each " terminator," as are necessitated by the maximum demand for simultaneous conversations between the two groups.

In the " terminator " the first idle " B " trunk is again connected with a selector which, upon the connection of the " B " trunk with the " A " trunk, receives the number signal. Immediately the connecting machinery establishes a contact between the " B " trunks and the contact element in the " terminator," representing the number of the subscriber wanted, which number has been transmitted to it.

Each subscriber, it will be understood, belongs to a certain group of 100, and in this group he possesses a contact element both in the " originator " and " terminator," these being connected to his line in parallel, protective devices being provided by means of which, as soon as the subscriber making a call has caused this particular contact-element in the " originator " to leave its normal position, his corresponding element in the " terminator " becomes inaccessible to other calls, and should any be made they would result in a " busy " signal.

The ringing up of subscribers, conversation and the clearing-out is done in precisely the same manner as in the direct method of connection previously described.

CERTAIN OF THE CONSTRUCTION DETAILS.

The "sender" is identical with that already described and employed upon the original type of the operator. The mechanism at the exchange, as I have already stated, embodies the "originator" "pilot," and "terminator."

The "Originator."—This consists of the switchboard, the movement and clearing-out device."

The switchboard consists of 100 perpendicular tracks, upon which 100 shuttles independently ride up and down. The track rails are insulated from one another, and connect in pairs to the subscribers' lines. The shuttles consist of two metallic parts in contact with the rails, but insulated from each other, each carrying a contact spring, by means of which they may be brought into contact with the "A" trunks.

The "A" trunks in the "originator" consist of horizontal metallic rods placed at right angles to the tracks, enabling each one of the shuttles to be brought into metallic contact with any one of the trunk rods. They are arranged in two parallel vertical planes, one in front of and the other behind the shuttle tracks. The ends of these rods are metallically connected to similarly disposed rods in the "pilot." It is self-evident, therefore, that when a subscriber's line is connected to an "A" trunk this is practically an extension of this line into the "pilot."

Each shuttle is provided with an actuating rod, by means of which it may be operated by motive power. In the position of rest, this rod is supported by a trip which, on being actuated by a magnet, allows the shuttle to drop. This magnet receives the current as soon as the subscriber winds his sender—this act resulting in putting the shuttle into its initial working position. The moment the shuttle reaches this position a projection upon its actuating rod protrudes into the path of a helical projection mounted on a continuously rotating drum, so that the shuttle is carried into its second working position.

The actuating rod cannot be moved further in this direction, owing to a stop in its path; consequently, the drum which is driven by friction is brought to a standstill. The moment this happens, the main mechanism is started, actuating the working beam which extends across the entire switchboard. A projection on this beam seizes the shuttle rod and lifts it into the so-called speaking position, *i.e.*, that in which its springs make contact with the first idle "A" trunk.

On completing its stroke, the working beam returns to rest.

This stops the connector movement, and the drum driven by friction is again started. The shuttle in the meantime remains in the position in which it was placed. In this position the shuttle actuating-rod rests upon a clearing-out bar, which prevents it from dropping back. There are as many of these clearing out bars as there are "A" trunks. These have a lateral movement, and when moved they release any shuttles which happen to be suspended from them. How this is accomplished will be referred to later.

At the next call the entire operation is repeated, save that the busy "A" trunk is "jumped" and the next one occupied, and so on.

The "Pilot."—In this we find again the switchboard movement, clearing-out apparatus, and in addition a group signal selector.

The construction of the switchboard is identical with that of the "originator," save that the drum is eliminated, and shuttle actuating-rods pass directly from position of rest into second working position.

The "A" trunks from the "originator" again terminate in rods, being provided with a branch circuit to the selector. These branch circuits are normally opened, and are opened during conversation over the trunks; being closed automatically part of the time during the switching act and during the transmission of the group signal.

The shuttles are here connected to rods in the various "terminators," so that the particular shuttle which is selected decides into which groups the subscriber's line will be extended.

The electrical stop motion in the subscriber's sender permits only partial running down of the "sender," but sufficient to transmit that part of the signal corresponding to the first two figures of the number desired. This is the group signal; and after its transmission, the selector in the "pilot" causes the particular shuttle to drop into working position. But immediately the shuttle reaches such a position, the actuating movement is started, and, as already described, establishes connection between the shuttle and that one of the "A" trunks over which the signal came. Thus, the subscriber's line is continued into that one "terminator" in which the subscriber's line which is desired is located; and it now remains to show how the particular line wanted is selected out of the hundred lines in that group. This will be shown in the description of the "terminator."

It is essential to mention here that the circuit, thus far built up, has in it a clearing-out magnet and parallel with that a non-inductive resistance. The province of the former being to maintain the established connection until the conversation is finished. A clearing-out in the "pilot" effects a clearing-out in the "originator."

The "Terminator."—Here we find again the switchboard actuating mechanism, clearing-out mechanism, signal selector, and the ringing apparatus.

The construction of the switchboard is identical with the ones already described, the 100 shuttles forming the terminals of the 100 lines of the group, and the metallic ends of the terminals of the "B" trunk which meet here coming from the different "pilots" where they had their beginning in shuttles.

All these rods have open branch circuits to the selector; but one of these branches at a time is closed temporarily the moment the "pilot" establishes connection between an "A" trunk, and a "B" trunk. Now, the sender is again released, and the transmission is effected. When the signal has been transmitted, the selector at the "terminator" effects the dropping of that one shuttle which carries the number wanted; and if its corresponding shuttle in the "originator" is idle, it is thus connected with a "B" trunk; thereby establishing connection between two subscribers.

In the other case the "busy" signal is given to the "originator," and the connection so far established is taken down.

Next, the ringing machinery is actuated, causing the signal at the called subscriber's instrument—this signal being repeated usually four times. It may be any number.

Should the subscriber not answer, the connection is cleared out, again.

As soon as the subscriber answers, the ringing mechanism is cut out and the talking battery is thrown in, so that no time is lost. On completion of the conversation the clearing-out magnet with its parallel resistance clears the line.

The comparison as to simplicity of operation in trunked calls is evidently still more in favor of this automatic system than even that shown in local calls—as the following comparison of operations necessary—shows.

Automatic.	Manual.
1. Subscriber sets "sender" and winds it up.	1. Subscriber takes off receiver. 2. Subscriber's individual light at exchange lights up, above pilot light.

2. Subscriber's shuttle drops.

3. Subscriber's shuttle is lifted into connection with an "A" trunk.

4. Subscriber's "sender" gives the group signal.

5. Pilot drops corresponding "B" trunk shuttle, and connects it with "A" trunk.

6 Subscriber's "sender" gives number signal.

7. Terminator drops called shuttle, or, if busy, gives busy signal, Otherwise connects shuttle with "B" trunk.

8. Terminator throws automatic key on called subscriber's line, ringing same.

9. Called subscriber and calling subscriber take off receiver.

10. Automatic key is restored, and talking battery throws on the line.

3. Operator places answering plug.

4. Operator varies listening key.

5. Operator asks number.

6. Subscriber gives number.

7. Operator repeats number.

8. Operator presses order wire key. Gets into communication with the trunk operator in the central office with which the called for subscriber is connected.

9. Operator gives number of subscriber wanted to *incoming* trunk operator at the second exchange.

10. *That* operator repeats number.

11. That operator gives number of idle trunk to be selected.

12. First operator releases order wire key.

13. First operator connects idle trunk to her cord circuit, thereby establishing connection between trunk and calling subscriber.

14. Second operator tests called subscriber's line, for busy using the trunk plug.

15. If idle, operator plugs multiple jack with trunk plug.

16. Second operator presses automatic key.

17. Automatic key rings subscriber.

18. Called subscriber takes off receiver, thereby restoring automatic key.

Next, conversation begins.

Upon its termination:

11. Calling subscriber hangs up.

Clearing-out magnet drops his connection in originator and pilot.

13. Called subscriber hangs up.

14. Clearing-out magnet drops balance of connection.

19. Calling subscriber hangs up receiver.

20. Supervising lamp at first operator's position lights up.

21. Called subscriber hangs up.

22. Second supervising lamp lights up.

23. First operator pulls out plugs.

24. Disconnect lamps at second operator's position light up.

25. Second operator pulls out trunk plug from multiple jack.

Special Classes of Service.

In modern telephone central exchange practice certain special classes of services are demanded; and these the automatic system already described will take care of in an eminently satisfactory manner; also adapting itself to the present central energy or common battery system, in a manner impossible with any other automatic exchange.

This system eliminates totally the large force of manual exchange operators, and only in the "toll service" the human operator is for the present essential.

I will consider in turn the manner in which the system would take care of each of these special classes of service.

"*Toll Connection.*"—A special number on the sender will be designated as "toll operator's" number at the exchange, she being called up just as any subscriber is. The operator then asks one what number is wished, and what the number of the calling party is, stating that she will call you when she gets the party you desire. This acts also as a check upon the service, and prevents a dishonest party giving another subscriber's number.

"*Restricted Service.*"—As in manual exchange practice, the toll operator would have a complete list of parties receiving such service, and decline to give any outsider long distance connection until he has been properly identified.

"*Appointment Calls,*"—As in manual exchange practice, these would be made through the toll clerk, who is communicated with through the operator's number on the sender.

"*Automatic Pay Station Service.*"—Such service would require a metering device, perferably a nickel-in-the-slot attachment. The nickel being returned in case no service is rendered. Or a metering device such as a cyclometer, responding to the action of the receiving hook, but *only* when circuits are established or service actually rendered. At the central exchange, a metering device would be operated in conjunction with the "busy test" apparatus, enabling the operator to check off such service, as in present manual exchange practice.

"*Inquiry Calls,*" "*Information Bureau,*" "*Complaints*" and "*Transmitted Messages.*"—In addition to the operators in the modern manual exchanges, information men, trouble men, etc. are employed to answer inquiries, attend to complaints, and transmit messages. The four classes above mentioned would be attended to in precisely the same manner.

"*Party Lines.*"—A four-party line selective ringing service can easily be given.

ADVANTAGES OF THIS AUTOMATIC SYSTEM OVER OTHERS.

The following points of advantage which are claimed for this automatic system have been investigated by me; and I deem them well worthy of consideration of every telephone engineer.

It is applicable to an exchange of any size.

It is applicable to the present standard central energy system.

It is applicable to any commercial telephone, and to the present arrangements of circuits met with in standard practice.

The total elimination of the multiple principle from this system makes it possible to sub-divide the exchange into several separate local exchanges together forming a large city system, and this without destroying the principle of unity in the system and without decreasing the speed of connection. In this manner a great economy in line construction and maintenance is effected.

It employs the usual protective devices of lightning arresters, heat coils, etc.

It gives a prompt service, the total time taken to transmit reliably a trunked signal of four figures, is about three-fifths of a second, and the average time to secure connection is found to be from three and one-half to four seconds.

It will give a more reliable service, and with equal efficiency at all times. Unlike the human operator it is never impatient nor impertinent, and does not become fatigued or ill, and does not drop in efficiency, under stress of the rush hours.

The saving of space occupied by this exchange will be very great, as compared with the space required for a multiple manual system. I am informed that the lowest calculation for space in cities is about a thousand square feet per one thousand subscribers, giving, say, ten thousand square feet for a ten thousand line exchange, and this is a *very conservative* estimate. In contrast it is claimed that 100 machines of 100 lines each, with sufficient lane-ways between each machine both ways, of say 2 feet, and a center lane of 3 feet, would only occupy 62 by 55 feet, or in all three thousand four hundred and ten feet.

It will do away with a large corps of skilled attendants at the switchboards, eliminating one of the heaviest expenses attendant upon the telephone industry.

It will do away with a percentage of employees necessary to keep the central station cables, wires and appliances in condition, and lessen the cost of inspection and maintenance.

It is claimed that it can be installed in large and medium sized exchanges, at 30 to 40 per cent. less cost than the present multiple

exchange system, and that the contacts in say, a ten thousand exchange would be 80 to 90 per cent. less in number than in a multiple exchange. It is possible to add at any time groups of 100 very easily without disturbing the existing installation, and thus increase from time to time in proportion to the demand. It would show much more nearly in a direct ratio an increase in expense of operation and fixed charges with the increase in the number of subscribers, than would be possible with the manual exchange which, as is well known, increases out of all proportion to the increase in the number of subscribers.

It will do away with employee's dressing, dining and reading rooms, clothes lockers, infirmary, matrons, etc., as well as considerable expense for ventilating plant, lighting and other sanitary arrangements necessitated by the usual crowding together of a large number of human operators in modern exchanges.

It permits of a large number of subscribers calling simultaneously, without producing confusion, the calls being stored up and brought into communication with the exchange in numerical rotation.

It requires a single piece of machinery for 100 lines, in contradistinction to the majority of automatic exchange systems, which require one machine to perform the switching for each subscriber's line.

A most important feature is, that it does away with the cords and multiple connections; and as the ground or drop connection is broken when the subscriber's carriage leaves its position of rest, a perfect balance of circuits is ensured, and the absolute isolation of each pair of communicating subscribers.

It gives a continuous trouble test, instantly throwing any line in which trouble has developed, either inside or outside the exchange, into communication with one of the lines, which may be the wire chief's. A permanent record is also made of these troubles.

It requires no batteries and no extra circuits at subscriber's stations, as in all other automatic systems.

It does not necessitate the subscriber's waiting to hear the operator ask "number ?" and repeat same to prevent error—thus saving the subscriber's time on each call.

It provides a sender which is "fool-proof," it being locked when operating, preventing further interference until signal is sent and properly received at the central exchange.

It does not require extra wiring, or even cutting of subscriber's

lines in order to install the sender; there being no mechanical connection of any kind between the subscriber's instrument and the sender; and the sender may be placed at the subscriber's telephone or at any convenient point. It is only necessary to connect it in parallel across the existing line, grounding the third binding post of the sender.

It necessitates no multiplicity of idle wires, crowding and complicating the working space, as in other exchanges, which amounts at times to 25 per cent. or more.

It requires but a single power driven pulley.

It embodies no parts operating at excessive speeds, in the original type of machine, the driving shaft being run at but 250 revolutions per minute with the operating parts driven by double back gearing at from 12 to 15 revolutions per minute.

It embodies in the mechanism of the original form, but four cams on a single shaft, each acting upon rollers; a single cam controlling all movements, with the exception of the ringing controller. In the new type of "operator," "sun and planet" gears take the place of the four cams in the original "operator."

It employs a single carriage with a connecting rod for each subscriber at central.

It provides a set of metal rods exactly corresponding to the connecting rods of the manual exchange in place of a large number of contacts constituting a multiple of all the lines in the exchange at each "selector," which is a predominant characteristic in all other automatic exchanges. It is substantially built with comparatively few wearing parts, and no telephone cords, plugs and jacks, line drops, lamps, relays, etc., to wear out; the cords being especially troublesome and expensive.

It requires but two operating batteries, no matter what the size of the exchange may be. One battery furnishes current to the switching apparatus, the other for conversation. Some automatic systems employ several batteries at the exchange, and in addition, a local battery at each subscriber's station.

It uses less current than the present multiple boards, as only one per cent. of the circuits of the exchange when idle receives any current at all, and that for but a fraction of a second. In some automatic exchange systems the current is very considerable, as compared with the maximum requirements of the exchange.

It makes and breaks every contact by power. No contact in the exchange is made or broken by means of an electro-magnet

(on the principle of a relay), not a single relay being employed on the machine.

It can coöperate with manual exchanges, and can call and be called by such exchanges.

It can be completely wired in sections at the factory, with the single exception of the "B" trunks; and at the place of installation it is only necessary to connect the "B" trunks to the "terminator," and to connect each subscriber's line once, a proceeding which is not possible in any installation employing the multiple system. It employs large contact surfaces. It handles all calls, no matter how many subscribers call at once. It possesses a perfectly balanced circuit at all times, having no multiple branches or taps. This is impossible with the manual or with automatic systems generally.

DISADVANTAGES OF THE MANUAL EXCHANGE SYSTEM.

Heavy disbursement for operators' salaries.

Important conversations between subscribers may be listened to by the operator and others at the exchange; and although this is not to be feared to any considerable extent in large exchanges, it is nevertheless a fact that the absolute privacy ensured by the automatic exchange system is highly appreciated by the telephone subscriber. At each call considerable of the subscriber's time is consumed in giving the operator the number desired, and having her repeat the same to prevent mistakes; and frequently the subscriber has to repeat the number several times by reason of his or her indistinct speaking, or standing too far from or too close to the transmitter; or by reason of disturbances on the line, or interference of other sounds in the proximity of the telephone. There may also be interference due to other subscribers being cut in on the lines.

During rush hours it has been necessary at times to station behind the usual operators, special operators, who facilitate the handling of the board by pulling out the various plugs. And it is not an uncommon practice when there are troubles at the switchboard, and possibly even during the congestion of the rush hours, for the operator to report a line busy, thus staving off temporarily the calling subscribers. Circumstances have been known where subscribers have been told repeatedly that the party whom they have called was busy; and on his making inquiry at that party's office he has found that the telephone had not been used during that period.

The reason why the multiple board deteriorates faster than the

balance of the installation lies in the fact that practically everything has to be sacrificed to considerations of space. A well-known telephone authority in this country has stated that the allowance for depreciation on the switchboard should not be less than 10 per cent; and while the common battery board is doubtless much better than the magneto board, it is believed that with this mechanical operator, with its large surfaces of contact and ample mechanical margins, the depreciation would be much less.

The cost of construction where the multiple section system is employed is enormous. It is a fact well understood by experienced telephone men that, as the number of the subscribers which are connected to any exchange (whether manual or automatic), increases, the expense, both of operation and maintenance increases in far greater proportion than the increase in the number of subscribers. This is not the case, however, with this automatic system, which, as regards the central exchange expenses and construction expenses and maintenance charges, increases more nearly in a direct proportion with the increase in the number of subscribers.

The length of reach of the human operator in the manual exchange is very limited. She is generally expected to cover a section of board 30 inches each side of her. This is not the case with this mechanical operator, the range of which is practically unlimited. Furthermore, in the latter case, the machine is not delayed by connecting and disconnecting, as it can connect and disconnect at one and the same time, a function which is not possible with the human operator.

In considering the disadvantages of automatic exchange systems hitherto invented, it is readily understood why they have met with such limited application up to date, notwithstanding the realization by telephone men the world over, of the many advantages of automatic exchanges; it is because of the inherent delicacy of the various electrical and mechanical devices employed and the rapid depreciation of these devices. It is also due to their extreme complexity, especially in the multiplication in the numbers of wires, contacts, relays, magnets, etc., which increase out of all proportion with the increase in the number of subscribers. It is quite common to employ from five to seven or more magnets and relays in each switching device, and employing one to three of these switching devices in establishing the necessary connections, and utilizing these magnets and relays for performing the actual mechanical work of lifting, rotating and

switching the mechanism employed with all the disadvantages which this entails; and finally, it is by reason of the very high class of engineering talent essential in the designing and constructing of the complicated apparatus which has been employed.

It is self-evident to all electrical engineers who have had experience with electromechanical devices that it is far better to employ a well-designed mechanism performing a definite cycle of operations and driven by some source of power.

This mechanical operator has been designed and constructed upon the following lines: *i.e.*, an absolutely reliable, prompt, rapid and uniform service in telephone exchanges of any size; an embodiment of all essential features demanded by the exigencies of modern telephone practice; an elimination of the unreliable, flimsy and complex features inherent in systems heretofore presented to the public; and finally, the effecting of large economies in construction and maintenance charges.

The author of this paper believes as a result of his investigations into this system, that these claims made for it will be borne out in actual practice; and he considers it a privilege to be able to present for your consideration what he believes to be one of the most important and interesting inventions ever brought before the AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS.

DISCUSSION.

PRESIDENT SCOTT:—Mr. Thomas D. Lockwood, electrical engineer and advisory electrician of the American Telephone and Telegraph Company, will read his paper on "The Evolution of the Telephone Switchboard."

MR. LOCKWOOD:—It will take a good paper to stand up to the introductory remarks of President Scott. It is a number of years since I last stood in this place, but the INSTITUTE, nevertheless, is always, and always has been, with me an object of solicitude; and I shall never, I think, be perfectly satisfied with the condition of the INSTITUTE until it has an audience room of its own far more fitted to its importance and requirements than this room, good as it is, can ever be. Perhaps, as President Scott has pertinently observed, there never was a greater invention than the speaking telephone. I do not think I am ever more impressed with its far-reaching consequence (and that is never absent from my mind, although I have been nearly twenty-five years connected with the telephone business) than when I sit in an office in Chicago and talk to my home near Boston. On such occasions the mystery of it comes over me, as I fear it can over very few persons; for when I think that one small iron plate can perform, under the influence of varying magnetism, and varying currents, all of the several functions which in the human individual require the coöperative work of the lungs, the palate, the lips and the tongue, I cannot but realize how great indeed is the intellect of man and how wonderful this one of his achievements. I was much impressed at a meeting held in Washington to celebrate the institution of the patent system of the United States, when an orator observed that while he felt that he could get upon familiar terms with a dynamo at a respectful distance, and while to some extent he could appreciate the electric telegraph as being something which even he was capable of measureably understanding, when it came to the telephone he was stricken with awe, for, as he said, while we have it on the authority of the Master that none of us by taking thought can add one cubit to his stature, Alexander Graham Bell by taking thought had added not merely a cubit but hundreds of miles to the length of our tongues and ears. I, therefore, you will understand, am one of the very last men in the world to belittle the telephone; and yet, standing here, as I do this evening, I am willing to asseverate even in this distinguished company, that the telephone without the telephone exchange system would have been incomplete; and that to the inventors who have perfected the plans for the telephone exchange, aided by the brilliant engineers who have made effective these plans, almost as much honor is due in the interest of commercialism, at least, as to him who laid the foundation for them—Alexander Graham Bell.

[Mr. Lockwood then read his paper (see page 127)].

MR. LOCKWOOD:—I did not intend to read as much of this

paper as I have, but it is the first time I have had a chance to read it, and I grew rather interested in the paper as I went along. If its contents have been to my audience but one-tenth as luminous as they are voluminous, I shall be perfectly satisfied.

(Vice-President Dr. Samuel Sheldon in the chair.)

VICE-PRESIDENT SHELDON:—I think we have all enjoyed this extremely interesting and valuable paper by Mr. Lockwood. It is doubtful if anyone else could have written so acceptably and so authoritatively on the subject. The discussion will be opened by Mr. J. J. Carty, chief engineer of the New York Telephone Company.

MR. J. J. CARTY:—To-night we have enjoyed the rare privilege of listening to a paper from Mr. Lockwood. The subject of his discourse is one of which he is the master. Condensed with admirable precision, he has put into 27 short pages an epitome of switchboard progress of the past twenty-five years. This was twenty-five years of intense effort, of struggle and failure, and of ultimate success. Within no similar period in history has there been displayed so much energy and so much successful work in connection with any industry. Of the magnificent results of this work the AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS has particular reason to feel proud.

Beginning with the telephone itself—the foundation of it all—we find it is the invention of one of our own members, Prof. Bell. I regret that he is not present with us to-night. In speaking of Prof. Bell, we cannot help but think also of another distinguished member, Mr. Edison, whose work in connection with the telephone is so well known to us all. Upon the foundation work of Prof. Bell down almost to the humblest improvement which has not yet been passed upon by Mr. Lockwood, this entire development has been the work almost exclusively of the members of this INSTITUTE. Nearly all of these electrical mechanisms of which we have heard to-night are the direct product of our own members, or have been produced by those coöperating with them or under their directions. I think, therefore, that in no other branch of electrical engineering can it be said that the AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS is more immediately concerned. In reference to no other branch of electrical work can it be said that they have reason to feel such a just pride.

It is not only as members of the AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS, but also as Americans, that we have reason to be proud of this work. It is nowadays the fashion to talk much, especially in the daily papers, about "American industrial supremacy." With braggadocio of that sort I have no sympathy. Nevertheless, for a special reason, it is pertinent to call attention to the fact that little,if any, contribution to the results described to-night has been made by any country except America. Of course, from this I must except the foundation work which was done by the noble band of immortals headed by Faraday, which the old world has produced. As specific

workers in the telephone field I must except two names—I refer to Van Rysselberghe of Belgium, who has given to us simultaneous telegraphy and telephony, and to the Rev. Mr. Hunning of the Church of England, who gave us the granular carbon transmitter. In the form in which we received it from him it was not fitted to survive this evolution of which we have heard to-night. It remained for an American, the late Mr. Anthony White, to convert the granular carbon transmitter of Hunning into the "solid back" transmitter of to-day.

Mr. Lockwood tells us of the successes which have been attained in telephone switchboards, but he has said little, if anything, of the failures. For every one of these successes there has been a multitude of failures. Many of the ideas which have been discussed have been contributed directly by Mr. Lockwood himself. With reference to many of the improvements, he has exercised great influence, and toward all of them has acted as a sort of godfather. With respect to the failures, his relation has not been so pleasant. Toward them he must be considered as being a "Lord High Executioner." I think it is safe to say that not a single important invention in relation to the telephone has been seriously proposed for the last twenty-five years, that has not been fully considered by Mr. Lockwood, and upon which he has not reported. In my experience I have found that he has rarely allowed a bad thing to pass by him without being properly stamped, and I have never known him to turn down a good thing. I am sure that there are a multitude of inventors who would not agree with me in this statement, but it is nevertheless true.

I had intended to offer some statistics showing what results might be obtained from systems employing the apparatus which Mr. Lockwood has so well described, but time will not permit, and there are many speakers to follow. I will give one fact, however, from our statistics which is very significant as showing the degree of practical perfection which telephonic apparatus has now reached. From carefully kept records of all the troubles in connection with the 100,000 telephone stations in Manhattan, it is found that each station is out of order during the year for a period of only 1 hour and 27 minutes. That means that on the average, each station would be in good order during the entire year, except for the brief period of 1 hour and 27 minutes. These figures are taken directly from carefully kept records. They are trustworthy and accurate.

VICE-PRESIDENT SHELDON:—The discussion will be continued by Mr. F. A. Pickernell, engineer of the American Telephone and Telegraph Company.

MR. PICKERNELL:—The subject has been so well covered in the paper which Mr. Lockwood presented that there is really not much opportunity for discussion. I do want to refer to one factor, however, that has been abundantly taken care of in the modern switchboards. You all remember in the early days of

telephony very many exhibitions were given of telephonic transmission between cities over lines of considerable length. Such development was not particularly rapid in the early days, because the number of stations was small, and some of the switchboard difficulties referred to had not been fixed up. However, as the switchboard was improved and the number of stations increased, the demand for long distance service, service between the cities, increased enormously, and every part of the apparatus used in switchboards had to be designed so that it would work satisfactorily in connection with such lines. A switchboard engineer, if he designed defective apparatus, might impair the service to an extent which could not be counterbalanced by the introduction of tons of copper in the long distance circuits. Some of those electromagnets in series which Mr. Lockwood referred to might not only impair the volume of transmission, but they might also introduce sources of disturbance due to their lack of electrical balance. All these things had to be cared for in designing switchboard equipment. The effort has been made and successfully carried out to arrange the apparatus so that any particular station may be connected with any other particular station within the range of say a thousand miles. The switchboard engineers have designed their apparatus so well that from the telephone station located in this building connection can probably be had with three-quarters of a million, if not a million, other stations in various parts of the country. None of these results could have been produced or attained if the switchboard design had not been of the highest possible order. That is the one thing I care to point out in connection with the subject under discussion this evening.

VICE-PRESIDENT SHELDON:—The discussion will be continued by Mr. B. Gherardi, Jr., chief engineer of the New York & New Jersey Telephone Company.

MR. GHERARDI:—The prevailing idea of the electrical engineer just graduating from college is that in telephony there is little for the engineer to do; that at best it furnishes only a field for the electrician or the mechanician. An instrument screwed upon the wall, a pair of twisted wires connected to it and an operator with some plugs and spring jacks at the central office, is all that is required. To be sure, it is not the daily task of the telephone engineer to design ponderous machinery such as is employed at Niagara; he is not concerned in transmitting for unheard of distances currents at enormous voltages; he does not make the grosser forms of engineering his exclusive concern. But it is a grave mistake to assume that with these branches of electrical engineering he has nothing whatever to do. The paper before us clearly brings out the multitudinous functions which must be performed by the modern telephone central office and indicates the variety of agencies which the telephone engineer has called to his aid.

Let us compare for a moment some of the functions of an

electric light station with those of a telephone central office. At the electric light station a certain gross amount of current is generated. This is distributed by feeders and mains through the various streets and highways of the district to be served and connections are made for the mains to the various houses requiring current. No particular unit of current generated at the central station is intended for any particular lamp or motor connected therewith. Large copper wires constituting the mains may be tapped to feed any house. The user of the electric light may turn on or off his current at will, and is not required to coöperate in any way with the central station, or with any of the other users of the electric light system.

In the telephone central office, however, there must be distributed from the central office current destined to a particular station, and this current, as a rule, is received at the central office from some other particular station where it originates. While in both electric light and telephone systems copper conductors are used, in the electric light system common conductors of large mass are employed. The current for all customers is sent out over these common wires.

In the telephone central office, while large amounts of copper are used, the particular current intended for a given station must be sent along its own conductors and delivered to its own destination. Not only must the central office arrangement provide for this, but it must provide that this current shall be delivered in the particular form and at a particular time, both of which shall be under the control of the subscriber.

The conductors leading to the electric light station extend to a switchboard, to be sure, but the connections there made are elementary in their character. Intercommunication between conductors centered at an electric light station is not the rule. In the telephone central office any line there centering must be so constituted that it can, within a fraction of a minute, be connected to any other line in the system. In a central office of ten thousand lines there are about one hundred million possible combinations of connections, which must be provided for. But it is not only subscribers in one central office that must be thought of, but connections between subscribers in different central offices must also be considered. This must be accomplished regardless of the number of central offices in any city. Not only this, but connections between any central office in a given city and between any central office in a neighboring city, must be capable of instantaneous establishment, and with the growth of the telephone system, the number of cities and towns which must be included within the vast network of wires has become practically unlimited.

Between the electric light system employed in the city of New York and that employed in the city of Boston, there is no necessary relation, but with the telephone system this is not so. The telephone system at Boston and the telephone system at

New York must be so constructed that they will be interlocking. This is true of all large cities which enter into the problem.

While, as I have stated, telephone engineers do not concern themselves with the transmission for great distances of high voltage currents, they have to contend with a transmission problem which in point of difficulties is of a vastly serious nature. Dealing, as it does, with currents defying measurement, and almost infinitesimal in amount, the work of the telephone engineer is attended by obstacles without number. Not only must the telephone engineer design his transmission system so as to take care of the currents generated by the telephone apparatus, but he must so plan that system that it will be defended against the inductive attacks of electric light and power circuits. For his own protection, therefore, if for no other reason, he must have a working knowledge of the behavior of currents of greater degree and higher voltage.

At the central office itself we have no Niagara dynamos, but we have an aggregartion of parts which may with precision be called a multitude. These parts, as Mr. Lockwood has so well pointed out, have varied and complex functions to perform. Each part has its special function, and must be maintained in definite relation to all of the other parts in the system.

Taken altogether, the demands upon the engineer in designing a modern telephone central office are not exceeded by those made upon engineers engaged in the grosser or heavier branches of the work.

I have mentioned this point, because, from observations I have made in visiting our various colleges in search of assistants from the graduating classes, I have found that the point of view which is taken by engineering students generally at these institutions is that which I have already indicated in my previous remarks. It is for this reason that I have made these comparisons, and not with a view of " blowing the horn " of the telephone engineer.

It would, perhaps, be interesting to enumerate briefly some of the electrical engineering branches which are represented in a modern telephone exchange. Wherever it is possible to obtain service such as is given so admirably to us at New York by the Edison Company, the prime source of current employed is from the street mains of the electric light company. To these are connected a motor, sometimes of 40 horse-power, and in reserve it is customary to keep an additional motor of this kind connected to the switchboard and ready for action at all times. Each of these motors is connected to a generator of suitable horse-power, which is employed to charge a storage battery. Where a direct current source of power is not available, two and three-phase alternating current motors are often employed, these being used to run the direct current charging generators. Often no electric current of any character is available for motor driving, and frequently such as may be available cannot be relied upon, and in

such cases gas engines or other prime movers are used, either as reserve or to furnish all of the power required. This use of direct current and two and three-phase alternating currents, and of gas engines and other prime movers, brings into the problem various factors of engineering supposed to belong exclusively to other branches and to be far removed from telephone engineering.

While the storage battery at a telephone central office is not to be compared in magnitude with those such as are used in our electric light stations, yet in so far as the care required in its maintenance and the knowledge of storage battery practice is concerned, the telephone engineer must be suitably equipped. He must at all times maintain the battery in condition to perform the service required of it.

From the storage battery are run various other motor-generators, which produce both direct and alternating current at various voltages to serve the diverse uses of the system. While the magnitude of the currents employed is not great, the necessity for absolute reliability is present and requires most exact and careful attention in design, installation and maintenance.

In the modern central office, the telephone switchboard is not the only one employed. To provide for the proper switching of the various machines and the prompt supplying of new sources of current in case of break-down, a power switchboard is needed. On this switchboard there are massive bus-bars, switches, fuses, circuit breakers, starting and regulating boxes, and the measuring instruments usually supposed to be peculiar to electric light and power stations. This apparatus, which I have just enumerated constitutes a complete power plant, and in its general aspects suggests an electric light station rather than a telephone office as ordinarily conceived.

Between this power plant and the telephone switchboard proper is drawn a dead line of specially designed fuses and cut-outs. In the consideration of these fuses and cut-outs alone the telephone engineer has been obliged to study questions which to the electric light engineer have probably not even occurred. Instead of large fusible wires or magnetic cut-outs carrying heavy currents, fine, hair-like fuses are employed, and in some cases we use heat coils surrounding easily fusible metal, which melts at a predetermined point and releases a spring which operates a cut-out or sends an alarm, as the case might be.

To the telephone man, a one-half ampere fuse is one that blows when that amount of current flows; to the electric light engineer, a one-half ampere fuse is one which will carry that amount of current plus an unknown quantity for an indefinite length of time. To tell the story of the fuse question as applied to telephony would be of great interest in itself, but in this discussion it can only be alluded to.

In the switchboard itself, as has already been clearly pointed out in the paper of the evening, there abounds a multitude of

questions involving intricate circuits, the mechanical disposition of a large number of parts, and the orderly arrangement of the whole so that it may at all times be ready to answer the various demands which are made upon it at all hours of the day and night. In every switchboard there are miles of conductors and cable, thousands of incandescent lamps, hundreds of relays, transformers, keyboard apparatus and other devices, each having its special function to perform, and which must be maintained at all times in a definite relation to all of the other parts. The orderly and economical arrangement of all of this aggregation of elements is one of the problems of the telephone engineer.

It is not the electric light engineer alone who has had to do with the development of transformers. Their extended use in telephony has called for a vast deal of time and study on the part of the telephone engineer, and while the transformer problem as presented to him is vastly different from that which is presented to the electric light engineer, it is still none the less difficult, and while in the design of transformers and other electric light and power apparatus, the degree of loss which should be tolerated is oftentimes dependent upon the cost of coal, we have no such conditions in telephony, for here the amount of current generated has absolute limit, and must be conserved in all of its parts if success is to be attained. Not only is there no margin for losses of current, but in respect to frequency and the shape of the wave, the telephone engineer is held to rigid limits.

The problem of centering at one point and housing such a large number of wires as are required in a modern telephone central office is a question requiring most careful study, and involves not only electrical, but also questions of mechanical and civil engineering. To terminate these wires properly and to provide for their distribution from time to time, as the varying demands of the business require, has been the subject of a great deal of study and invention on the part of many minds.

The size and efficiency of the underground cable, depending not only upon its conductor resistance, but also upon the dielectric capacity, influences the size and number of ducts in the underground cable system. This in turn affects the size of the office district which it is economical to serve, and this, taken together with a large number of other factors, determines the size of the central office. The switchboard design depends upon the size of the offices, and this, as I have indicated, is, in a large measure, dependent upon the character of the cable it is possible to employ. Thus slight changes in cable design, apparently having no relation whatever to the central office apparatus, are often found to affect its design.

In view of the vast costs and peculiar requirements of the modern telephone switchboard, it is rarely that a building already constructed can be found well adapted for the purpose of a telephone central office of any considerable magnitude. For this reason, a specially designed building must be prepared,

and ordinary prudence requires that this building should be as nearly as possible fire-proof. The construction of the building bears such a close relation to the arrangement of the telephonic apparatus that it must be subordinate thereto. For this reason there devolves upon the telephone engineer the task in the first instance of designing the telephone central office building before the matter is turned over to the architect.

All of these things have been brought to my mind by a perusal of this most valuable paper of Mr. Lockwood's, and perhaps at the risk of being irrelevant, I have felt it worth while at least to mention them in the discussion.

VICE-PRESIDENT SHELDON:—Will Mr. E. F. Sherwood, superintendent of traffic of the New York Telephone Company, please continue the discussion.

MR. SHERWOOD:—The title of the paper of the evening is of itself sufficient to attract the favorable attention of all engaged in telephony, but coming as it does from Mr. Lockwood, whose relations to the subject are so well known to us all, it is doubly interesting. What he has to-night told us may be taken with all the weight of authority. He has rapidly sketched for our interest and information the progress of the switchboard from its imperfect beginnings to that high degree of perfection which it has attained to-day. But all of the care and thought and effort which have been applied by the ablest engineers to the design and construction of the modern switchboard would go for naught unless, after the switchboard is installed, it is operated in accordance with correct methods. These methods themselves have gone through the same harsh process of evolution which has given to us the splendid mechanism of to-day. Indeed, the relation between the method of operation and the design of switchboards is so close that there has often been controversy as to which was the more important. Into a discussion of this matter it is not now my intention to enter, but I will say that as between operating method and switchboard design there is, when rightly considered, no necessary conflict. Each must be adjusted to the other and their correct mutual relations must be established. It is a fact not without significance that between the highest type of switchboard design and the best operating methods, there is no incompatibility. Both may be found together in the same organization, each in its highest form. In fact, I am convinced that in the highest form one cannot exist without the other.

In the paper itself, as well as in the discussion, the physical features of the switchboard system have been developed at length. For my own remarks, I think it might be of interest if I should present in brief form data which will give some idea of the results which may be obtained from the relay board such as Mr. Lockwood describes. I have taken data as applying to New York, because it is with traffic of that company I am particularly familiar.

For the past eight years it has been the practice in New York

to make service tests in such a way as to show the quality of the service received by telephone subscribers. These tests show the time taken by the operator to answer subscribers' calls, the time taken to complete local and trunk connections, the time taken to disconnect after conversations are finished, the percentage of connections on which irregularities occur, etc. Records of these tests have been valuable not only as a means of showing in what respects improvements in the service might be made, but have afforded accurate information as to the improvements brought about by the installation of relay switchboards.

The first standard relay switchboard installed in New York was cut into service on November 13, 1898, and the last one, which for Manhattan Island rounded out the conversion of the entire system of local switchboards to a relay basis, was cut into service November 2, 1901. The tests of service for the year preceding the installation of the first relay switchboard in New York and for the year 1902 show the following results:

	Avg. time taken by operator to answer.	Avg. time taken to complete local connections.	Avg time taken to complete trunk connections.	Avg. time taken to disconnect.
1897	7.7	27.6	50.7	17.1
1902	3.8	23.7	30.7	2.8

The improvement made in the time of answering is chiefly due to two causes: First, unlike the arrangement of magneto equipment, the answering jacks in the relay board are immediately associated with the line lamps or calling signals, so that no time is lost by the operator in locating the answering jack corresponding with the calling signal; and second, with relay equipment subscriber's lines are promptly released after conversations are finished, and delays due to slow clearing out of previous connectious do not occur as they did with magneto equipment, which required that operators should listen in and ask "are you through?" in every case before disconnecting.

The improvement in the time taken to complete connections is partly due to the use of trunk line machine ringing keys, which when set, cause the bell of the called subscriber to ring intermittently until the receiver is removed from the hook; and partly to the use of cord supervisory signals, which show whether the called subscriber has answered or not and enable the operator to give a second or a third ring when necessary, without delay.

The slowness of disconnection, with the old type magneto switchboard, to which Mr. Lockwood referred, was largely due to the failure of the subscriber to ring off in a large percentage of cases—something like 14 per cent. of the subscribers hung up their telephone without giving any signal, and the operator had to discover whether the subscriber had finished by groping around and listening on the line.

The improvement in the time of disconnection is entirely due to the use of cord supervisory signals, which immediately light when the receiver is placed on the hook, and enable the operator to

disconnect without listening in on the connection. In fact, the work of making disconnections is largely an overlapping operation, and is frequently performed simultaneously with other operations which require the use of the operator's telephone.

Further evidence that the installation of relay switchboards has improved the service is furnished by the record of written complaints from subscribers. During the year 1897, when the average number of subscriber's lines in service in Manhattan was 17,066, a daily average of 3.2 written complaints were received or one complaint a day for every 5,330 lines. During the year 1902, when the average number of subscribers' lines in service in Manhattan was 49,955, a daily average of 3.3 written complaints were received, or only one complaint a day for every 15,138 lines; or to put it another way, at the rate of one complaint for each line every 41 years.

The relay switchboards in New York have been put to the most severe test, and have stood that test in a most satisfactory manner. Since the installation of the first relay board in New York, the number of lines in Manhattan has increased from 20,740 to 53,792, and the number of stations in Manhattan has increased from 25,516 to 91,945. During this time the daily average number of calls originated by subscribers has increased from 243,590 to 549,940, and the daily average number of connections handled by each subscriber operator has been increased from 750 to 1070; and yet, with this very large increase in lines, stations and traffic, and the material increase in the number of calls handled by each operator, the relay switchboards have enabled us to make a very substantial improvement in the service.

The evolution of the telephone switchboard, which has resulted in standardizing such equipment and has permitted us to install uniform equipment throughout Manhattan Island, has made it possible to establish a school for the instruction and training of new operators; and such a school was established by the New York Telephone Company on February 1, 1902. This school is equipped with a switchboard, which on a small scale is just as complete as any switchboard in service, and is so designed that all types of calls are handled by the student operators in practice in exactly the same way that they are handled at the regular central offices.

In this school student operators are thoroughly instructed in the theory and practice of telephone operating. They attend twelve lectures given by the head of the school, and after each lecture they put in practice at the school switchboard the instructions given in the lecture. In this way they learn how to handle properly the switchboard apparatus, trunk lines, etc., and also learn by actual practice the methods of handling the various classes of traffic. The course of instructions is such that on being transferred to a regular central office, student operators are competent to handle moderately busy switchboard positions.

Before the operators' school was established, the new opera-

tors were sent to the various central offices, and were instructed by experienced operators, who devoted to them as much time as could be spared from their regular duties and permitted them to practice at the switchboard when the traffic was light. The great disadvantages of this method of training operators were that students had a great deal of time during which they were not occupied except in listening in with another operator and when they first began to handle subscribers' calls, they necessarily were not so proficient as operators who have had experience at the school switchboard.

The principal advantages of our present method of instructing new operators over the old method of training them in the various central offices are as follows:

1.—The raw student element has been entirely eliminated from the central office, thereby greatly reducing the amount of interference with the service caused by inexperienced operators.

2.—The students in being trained by expert teachers acquire a uniformity of method, which has proved to be very beneficial.

3.—The time required to develop a new operator into an expert operator has been reduced two months by the establishment of the school.

4.—The total cost of training operators in the school is less than it was when they were educated in the various central offices.

The necessity for our present method of training operators becomes apparent when it is understood that in order to fill vacancies caused by resignations and to fill positions caused by the increase in the New York Telephone Company's business, and to supply operators for subscribers who take private branch exchange switchboards, of which there are 3,300 in Manhattan, we are obliged to train upwards of 700 operators a year. It is interesting to note in this connection, that there are more than twice as many operators employed in operating private branch exchange switchboards as are engaged in the various central offices in Manhattan.

With the evolution of the telephone switchboard, as I have already pointed out, there has gone on a corresponding development in the methods of operation, or handling the "traffic," as it is nowadays called. This development is by no means limited to the mere routine to be followed by operators in working the switchboard. It has been applied to the founding of the Traffic Department, the organization immediately charged with the duty of giving at all times to the public prompt and satisfactory service. So large have some of these departments grown that, in the number of their employees, the complexity of their organization, and the importance of their work, they may be compared to the entire organization of a telephone company of years ago.

From the facts which Mr. Gherardi has so clearly brought out in his remarks, there can be no doubt that among the various branches of electrical engineering, that of the telephone engineer

deserves a high rank. In addition to the varied demands now made upon the telephone engineer, there are many others which might be mentioned. So comprehensive is the subject that there are in telephone engineering already, specialties and sub-specialties.

To deal adequately with the traffic questions and operating methods required in connection with growing systems and changing types of switchboard, there has come a demand for the telephone engineer specially skilled in these matters. In all of the large telephone companies nowadays, we have a traffic engineer, whose special duty it is to study switchboard problems in their particular relations to operating methods.

To give even a slight idea of the nature of the problems encountered in traffic departments, would require a paper devoted to that subject alone. In my remarks I simply intended to call attention to problems, the nature of which are not generally understood, and the very existence of which is probably known to but few outside of those immediately concerned.

VICE-PRESIDENT SHELDON:—The next speaker on the programme is Mr. G. C. Allen, superintendent of construction of the New York Telephone Company.

MR. ALLEN:—It was with great interest that I read the advance sheets of the able paper which Mr. Lockwood has presented to us to-night. After studying with much care the splendid presentation which he has made of an intricate subject, I have wondered why it is that I should have been asked to discuss a paper dealing so particularly with central office apparatus. But after giving some thought to the subject, I have concluded that while the central office apparatus is of controlling importance in telephone systems, that, after all, it would be of little use unless it were supplemented by adequate provision for the outside plant. It is to the design and construction of the outside plant that my work in telephony has for the past fifteen years been especially directed. The central office apparatus may be considered as the cerebral headquarters of the telephone system; it is the brains of the working plant. But as the brain, without nerves extending to all parts of the body, would be unable to perform its function, so would a telephone central office be without purpose unless there were leading from it to all parts of the district served, suitable conductors coöperating with the organization represented at the central office.

In the paper which we have before us for discussion, there has been briefly traced the history of the development of the telephone switchboard and the essential principles of the existing system, which has survived from a multitude of failures. This description is notable for its accurate brevity and for its clear and forcible statement of an involved subject. It has been ably pointed out by Mr. Gherardi that the installation of the modern telephone switchboard has drawn upon the resources of electrical engineering in practically all of its departments. I shall confine

my remarks to explaining some of the new demands which have been made upon the telephone engineer to adapt the outside plant to modern conditions and to bring it up in point of efficiency to the standard set at the central office.

With the old magneto system there was upon the lines no normal current. Under ordinary conditions, that is, when the telephone lines were not in use, no current was flowing upon the subscribers' lines. The only current which these lines had to carry was the occasional ringing current employed when signalling a subscriber, and the minute telephone current impressed upon the line during conversation. Neither of these currents imposed upon the conductor or its dielectric any substantial strain. With the common battery system, however, there is upon the line at all times an electromotive force of 24 volts and during conversation there is a current flowing, although in small amount. The strain put upon the dielectric of the conductor by such a small voltage as that employed is not in any sense to be compared with that encountered in electric light practice, but considering the large number of wires which must be placed in one cable and considering the small amount of insulating material with which it is practicable to enclose the conductors, the strain is by no means negligible and as compared with former conditions, it is most substantial. Perhaps in employing the word "strain," I am conveying an erroneous idea, but when we consider the presence of a very small voltage upon the line for a long period of time, possibilities of destructive effects in the dielectric are present to a considerable degree. For this reason, an unusual amount of care is required in the maintenance of cables connected with common battery systems. The same is true of all of the wiring in the outside circuits.

As is now well understood, paper has been universally accepted as being for telephone conductors altogether the best insulating medium to employ, both on account of its low inductive capacity, as well as on account of its high insulating qualities. But these high insulating qualities of paper are present only so long as the paper is kept free from moisture. Even small amounts of moisture, which might in chemical language be referred to as "traces" will produce a lowering of the insulation which is not allowable in the best practice. For this reason, the methods of laying and maintaining cable have become more and more rigorous as our experience with this new switchboard system has progressed. Notwithstanding this, the development of engineering practice as applied to the outside plant has kept pace with that which has been applied to the central office apparatus.

Periodical insulation tests are made and incipient faults are immediately noted and steps at once taken for their rectification. It is now a matter of every-day practice by means of electrical measurements, to locate within a few feet faults in cables, whether due to the discontinuity of the conductors or to a failure of insulation.

With the advances of central office construction and with the enormous increase in conductors in such cities as New York, has come a greater extension of underground wires. At the present time I think it may be stated without fear of contradiction that considering the total mileage of wire employed, that a larger percentage in mileage of the conductors on Manhattan Island is underground than may be found in cities elsewhere. At the present time on Manhattan Island there are installed as part of the telephone system, outside of the company's exchanges, 222,543 miles of telephone conductors. Of this vast mileage of wire, 98.08 per cent. is wholly underground. Substantially all of these wires are paper insulated and covered with lead pipes. Within these lead pipes the paper insulated wires must be hermetically sealed. Exposure to the air due to a perforation of the lead pipe, even so small as a pin head, would result in the ultimate failure of the cable. This perforation of the lead pipe is as certain to produce trouble in the underground cable as a perforation in a can containing vegetables would be attended by the decay of its contents.

To give an idea of the magnitude of the task of maintaining all of these wires in lead pipes which shall be practically hermetically sealed, I may state that the total area of the lead covering required to enclose these 222,543 miles of conductors amounts to more than fifty acres. Had it been known at the inception of the telephone that the full working out of the idea of Prof. Bell would require the maintenance of such conditions, it is safe to say that at that time, no one could have been found who would give countenance to such a fool-hardy project.

The early practice of the telephone art was to employ for its cables gutta-percha or rubber-covered wires. This was natural enough in view of the fact that telegraph men were, as Mr. Lockwood has pointed out, among the first telephonists, and in telegraph-cable practice rubber and gutta-percha, particularly as applied to submarine cables, was then and is still a well-established usage. But in telephony the peculiar effects of capacity were particularly troublesome and drove us to the use of a dielectric having a low inductive capacity. In paper we have found a material which, up to the present time, has proved to be the best to use, notwithstanding its susceptibility to the influences of moisture. The maintenance of so vast a network of paper cables as is required for such a system as that of Manhattan Island is possible only by the exercise of eternal vigilance. The last central office converted from the magneto to the standard type of switchboard was the Cortlandt street office, which was corrected a year ago. The work of establishing the new central office involved an additional story on the building, putting in a new switchboard and a rearrangement of all cables. Some of the cables had to be handled two or three times, and there were over twenty thousand to be handled and re-terminated in the new terminal room and connected to the switchboard. When the

switchboard went into service on Monday morning—we generally do work of this character on Sunday—it was found that five or six of the circuits were misplaced and that connections on ten or twelve had not been properly made. These troubles were remedied, and the rest of the subscribers did not realize a change had been made in the system. The continued extensions and re-arrangements of the plant due to growth and changes in the city, and to the establishment and re-arrangement of central offices, require a degree of attention in the employment of such a large staff of engineers, that, could it have been realized at the beginning, would have been sufficient to have dissuaded any but the rashest of men from undertaking the development of what has proved to be one of the most important adjuncts to modern civilization—the telephone exchange.

VICE-PREISDENT SHELDON:—Mr. William J. Hammer will now present his paper entitled, "An Automatic Telephone Operator."

[Mr. Hammer then read his paper (see page 155)].

VICE-PRESIDENT SHELDON:—Mr. L. W. Stanton is on the programme to participate in the discussion, but I understand he is not present just now. The hour is so late that we will not have any further discussion, with the exception of some closing remarks by Mr. Lockwood.

MR. LOCKWOOD:—I shall not keep the gentlemen more than a very few minutes. I am in the unusual position of being able to agree with all of the discussion. I thought when I came into this room that I really knew something more about the telephone exchange business than I find is the case. I have learned as much as any man in the room from the gentlemen who followed in the discussion after the reading of my paper. There are many things with which I was, of course, familiar in a general way, but the details never had been brought to my notice in such a forcible manner as they have been this evening. Mr. Gherardi's remark about the necessity for coördinating the stations in large cities, for example, cities like New York and Boston, was highly interesting. That is a remarkable thing, but it is not a matter which is reached in a moment; and the necessity for coördination was not apparent until after the long-distance telephone had rendered commercial service and rendered it well. I also was much instructed and interested in his statement, which I perhaps may paraphrase, that the telephone engineer has to be more kinds of an electrical engineer than perhaps any other electrical engineer following a specialty. That may sound paradoxical, and sophistical, but it is true; and I have been accustomed to congratulate young telephone engineers on the fact that having to deal with the weakest current which is employed industrially and thus with the most sensitive instruments, they must also be familiar with the operation of all other currents, and the systems wherein such other currents work; so that whenever any question arises, they may be able to handle it with intelligence and

ability, even though it concern engineering work, dealing mainly with heavy current utilization. It is certainly a fact that to be a telephone engineer of the first rank, a man must also be a good mechanical engineer, and a good electrical engineer on the broadest lines.

I was also interested in and instructed by Mr. Sherwood's description of the training school for telephone operators; by his account of the wonderfully low average of complaints and faults; and by his statements concerning the resignations of operators and the difficulty in maintaining the supply of good ones. Within my own experience, marriage has always been an active agency in depleting the force of operators; and a number of operators have married patrons of the telephone exchange.

Of course, no one at this hour could seriously think of devoting discussion to the paper upon a new subject which Mr. Hammer has brought before us; but I think we can all agree that the "mechanical operator" of which he spoke does indeed have one advantage over the human operator now generally employed. It will not resign to the number of 700 within a year because it is desirous of marrying; and our wildest dreams cannot, I am sure, suggest the conceivability of a telephone subscriber—in any contingency—wanting to marry one of Mr. Hammer's "mechanical operators."

MR. F. E. KINSMAN:—Mr. Lockwood omitted reference to the first telephone exchange established in Boston. He said, if I recall, that it was a connection made by twisting a wire from one post to another. As a matter of fact, I was employed in Boston in August, 1877, and my recollection is that the first exchange was operated by transmitting the message through the operator. If the hour were not so late, I would give you some more points on that subject. That was the first exchange established in Boston.

MR. LOCKWOOD:—There is a brief reply needed to the last remark. The first exchange was established in Boston in May, 1877, through some burglar alarm wires. But of course Mr. Kinsman has observed that my paper concerns the "Evolution of the Telephone Switchboard," and does not in any sense profess to be an historical account of the rise and progress of the telephone exchange system.

MR. KINSMAN:—I will take the correction as to date; but I will say that the exchange was first introduced in Mr. Holmes's burglar alarm office and it was made by the operator taking the message and turning about and talking through the telephone to the party to whom the message was to be given. I was there and helped in the work.

[The meeting then adjourned].

BRANCH DISCUSSIONS.

Discussion at St. Louis, Jan. 23, 1903.

The meeting was called to order at 8.15 P.M., in the rooms of the Engineers' Club, by Mr. Rustin.

The minutes of the preceding meeting were read and approved, after which the reports from the various committees were called for.

Mr. Klauder, who had been appointed to see the Managing Board of the Engineers' Club, not being present, Mr. Humphrey made a report in his stead, stating that the Managing Board of the Engineers' Club had been very cordial saying that they hoped the local branch would use their club rooms as headquarters, the charge for rental being $10.00 per meeting, or for ten meetings per year, $100.00; also that the date of meeting—the third Friday in each month—would be entirely satisfactory.

It was moved by Mr. Humphrey, seconded by Mr. Langsdorf, that Mr. Klauder's report be accepted and his recommendations carried out. Motion was carried.

The paper of the evening, "Evolution of the Modern Telephone Switchboard, by T. D. Lockwood, was then read by the Secretary.

The discussion was participated in by:

Mr. O'Rielly, Supervisor of City Lighting; Mr. Mott, Chief Engineer of the Bell Telephone Company; Mr. Humphrey, Consulting Engineer; Mr. Harrison, Wire Chief, Kinloch Telephone Company; Mr. Crawshaw, Superintendent of Exchanges, Bell Telephone Co.; Mr. Devine, formerly connected with the earliest telephone exchanges in the city of St. Louis. Mr. Byrnes, Superintendent of Equipment, Bell Telephone Company; Mr. Welz, World's Fair Department of Electricity; Mr. Skinner, of the Western Electric Co., Mr. Rausch, consulting engineer; Mr. Reber, Secretary of the Kinloch Telephone Company.

The discussion was quite spirited and brought out many interesting points in regard to the paper, also in regard to the local situation.

The meeting was attended by 32 men, of whom 12 were members of the American Institute of Electrical Engineers. Of the 20 visitors present, 12 made applications for Associate membership. In addition, three applications for Associate membership were presented from men who were not present at the meeting.

Announcement was made that the next meeting of the Local Branch would be held Friday evening, February 27th, the subject to be discussed, "Railway Train Lighting."

Gerard Swope,
Secretary.

Discussion at Ohio State University, Feb. 4, 1903.

Prof. F. C. Caldwell in the Chair.

Mr. Thomas D. Lockwood's paper on "The Evolution of the Telephone Switchboard," was read by Mr. C. F. Kettering. The meeting was considered profitable by the students, about 40 of whom were present. The outlook for a successful future is promising.

F. C. Caldwell.
Secretary.

Discussion at Pittsburg, Feb. 5, 1903.

Telephony.

Programme:

President's remarks at the New York Meeting read by Secretary, J. S. Peck.

"An Automatic Telephone Operator," by Mr. W. J. Hammer, abstracted by Prof. S. M. Kintner.

"Evolution of the Telephone Switchboard," by Mr. Thos. D. Lockwood, abstracted by Mr. S. P. Grace.

Exhibition and Description of Arcophone, or Talking Arc Lamp, by Mr. R. A. L. Snyder.

General Discussion.

The discussion was participated in by Mr. S. P. Grace, Mr. Charles Bradley, Mr. P. M. Lincoln, Mr. Gallegher and Mr. L. Hommel.

Mr. Grace.—Mr. Lockwood in his paper on the Evolution of the Telephone Switchboard has admirably described the manner in which the present perfected arrangement of switchboards developed from the crude switching devices of the early days of the telephone.

Mr. Lockwood has also given a very complete description of a modern common-battery telephone switchboard, and has also shown and described the line of investigation which was pursued to attain this development. It is not necessary for me to add anything more on the evolution of the telephone switchboard, since Mr. Lockwood has covered this matter in such an admirable manner; I shall simply call attention to a few of the great advantages that the common-battery system possesses. We may sub-divide the advantages accruing from the common-battery system into three general heads:

1. Improvements in operating.

2. Economy of maintenance.
3. Quality of service.

In discussing the question of operating, it is, perhaps, instructive to look back and see the difficulties under which the operator worked under the old arrangement of magneto switchboards. The switchboard was arranged with a large number of annunciators or drops mounted on the face of the switchboard near the top. When a subscriber turned the crank at his telephone, his annunciator was displayed in front of the operator, who had to look up at the annunciator, ascertain its number, and then hunt out the corresponding answering jack in which to plug. This kept the telephone operator's head tilted upward at an awkward and disagreeable angle.

In the common-battery system the subscriber merely removes the receiver from the hook, which act lights a small incandescent lamp immediately adjacent to the answering jack belonging to the calling subscriber. The operator in answering does not have to ascertain the particular number calling, but merely "plugs out" the light. This act alone increases the speed of operating from three to four seconds.

Another great disadvantage of the magneto system was the entire absence of supervisory signals, *i.e.*, the operator had no means of knowing when the calling or called subscriber was at the telephone. The only arrangement for disconnection was a clearing-out drop bridged across the cord circuit. It was necessary for the subscriber to ring off when through using the line.

Undoubtedly, many of you have run across the sign painted in large letters on the telephone, "Ring off." But it is human nature to do as little as possible when once you receive the benefit asked for; so, while all the subscribers would ring in to get central, but a very small percentage of them would remember the injunction to "ring off."

In the common-battery system there is placed a supervisory-lamp signal on each side of the cord circuit, which is used to connect together two subscribers' lines. When a subscriber is rung by the operator, one of these lamps remains lighted until he answers. When both subscribers are finished with the conversation the simple act of hanging the receiver upon the hook lights both of these supervisory-lamps, which is a signal to the operator that that pair or cords, and consequently the connected lines, are no longer in use. She will, therefore, immediately remove the connection. If either one of the subscribers wishes to call in the operator during the course of a connection, it can be done by simply working the hook up and down, which flashes the supervisory signal. It is thus seen that for all local connections the operator has complete supervision over the calls.

It is, however, in a multiple office district, such as Pittsburg, where the advantages of the common battery system are particularly in evidence. In such a district is it necessary to operate

a number of offices and arrange for trunking connections between them.

In the magneto system there were provided no supervisory or disconnect signals on these trunk lines. This made the operation of them extremely difficult and also impaired the quality of the service rendered, since the operators would frequently make mistakes and take down the connection before the conversation was finished.

In the modern common-battery system, when a call is received for a line in a distant office, the operator who receives the call cuts in directly on what is known as a calling circuit wire, to an operator who is located at the exchange which contains the line asked for. This operator assigns a trunk to be used and at the same time plugs the trunk which ends in a plug and cord into the line asked for. The originating operator, of course, plugs into the other end of the trunk line. When both subscribers are through talking, the disconnect signals are received by the originating operator in the usual manner, who will take down the connection. The taking of the plug out of the trunk line automatically gives the trunk operator at the distant exchange a disconnect signal to show her that the trunk line is no longer in use. She will then remove the trunk line from the local subscribers' line. Similar automatic trunks are provided for use between the local boards and the long distance boards. It will thus be seen that from an operating standpoint the common-battery system removes the necessity of the personal supervision of calls by the operator, automatic signals being the means of warning her of all stages of the connection.

The common-battery system also enables us to increase the operator's load, which means that an operator can answer more telephones than in the old style systems. Our payrolls show that with a first-class common-battery system we can handle the same business with about 20 per cent. less number of operators. The common-battery system is therefore easier and cheaper to operate than the old style system.

Economy of Maintenance.—In the magneto systems each individual telephone was a small edition of a central office power plant. We provided batteries for furnishing the direct transmitter current and a complicated magneto generator for furnishing alternating current for signalling the central office.

Anyone who has had experience in the maintenance of even a small central office power plant will recognize the difficulty and the expense of maintaining these thousands of isolated power plants which were located in each telephone. The maintenance of this generating outfit was from $2.00 to $3.00 per year per telephone. But in the common-battery system all these isolated power plants are done away with, and a single central office power plant suffices for the entire exchange. One large storage battery, consisting of eleven (11) cells, is installed. This main battery is charged from motor generators from off the lighting

mains and supplies all the current used in the telephone exchange. The cost of all current supply per telephone, including the fixed charges, probably does not exceed $1.00 per telephone per year in a modern common-battery system. The removal of the generators and batteries from the instrument has also cheapened its first cost and maintenance, and the instrument as it exists to-day contains the fewest possible number of parts.

It might be well to remark at this juncture that the successful operation of the common-battery system depended upon the evolution of the storage battery. We had to have at the central office a source of current of constant e.m.f. and which possessed practically no internal resistance. If the source of power were not constant or contained any internal resistance, all the lines connected with the exchange would be noisy or would have cross-talk on them. As is well known, the modern storage battery produces a current of constant e.m.f., and it besides possesses a very low internal resistance, these two features making possible the common-battery system of to-day.

In the common-battery system there is a pressure of 24 volts on every line all the time, and any poor or defective insulation will cause a leak of current and consequently the display of the signalling apparatus at the central office.

One of the great objections to the use of common-battery by telephone engineers was the fact that it required superior outside line construction, but this in reality has been a benefit, for with the common-battery system we must put our wires and cables underground and use as little open wire as possible, in order to obtain a good quality of service. Also the current being upon the lines at all times, it acts as a sort of watch dog to the entire system, and makes those in charge of the plant keep it in good repair.

From the above statements the economy of maintenance of the common-battery system is plainly apparent.

Service.—From the subscribers' standpoint the common-battery system is eminently satisfactory. He is not required to grind a crank in order to signal central. All he has to do is to remove the telephone from the hook which immediately displays the signal in front of the operator. This gives the subscriber practically nothing to do and transfers all work to the central office, where it can be taken care of by skilled operators. It is always possible for the subscriber to call in the operator by moving the hook, and the possibility of his being hung up and unable to get the central office is very remote.

That the subscriber is satisfied with the common-battery system is evidenced from the fact that in ordering a telephone or a private branch exchange he will always tell you "that he wants that system where you take the receiver off the hook and it lights one of those little lamps."

I have stated above that in the old systems batteries were provided for each telephone for supplying the transmitter with

current. When these batteries were new and in good condition, the service from the telephone was good, but after they had been used for a short time, or if the subscriber accidentally left the receiver off the hook and thus allowed the batteries to run down, the transmission from the telephone would be very poor. Therefore, from the magneto system, with local batteries, we never could hope to obtain a uniform grade of service.

It is highly necessary that all of the instruments talk well over both local and long-distance lines, for it is our aim and ambition to produce a satisfactory volume of transmission between all telephones in the entire country. In the local battery system, if we spent a large amount of money in battery maintenance and kept the batteries in first-class order, the transmission for all local connections would be entirely too strong, although it must be admitted that it would be excellent for the long-distance connections. In the common-battery system the source of current supply is from the central office battery and we can, therefore regulate the amount of current for each connection; *i.e.*, for all local service we will have our apparatus so wired that the instrument receives sufficient current for local transmission, but when a long-distance connection is put up we will triple or quadruple the amount of current given to the transmitter. Thus, with the common-battery system we are enabled to give an absolutely uniform grade of transmission for all local connections, and for long-distance connections we can give the transmitter the ultimate amount of battery power that it will stand. This, in my opinion, is one of the most important advantages of the common-battery system.

So successful has the common-battery system proved in large exchanges that it is now the intention to carry the work still further and make even the smallest exchanges in country towns work on the common-battery basis. Plans have been prepared for a number of these small exchanges, which will work on the common-battery basis, but which will be provided with no power plant. The necessary current for operating the transmitters and signals will be supplied from the nearest large common-battery plant.

In conclusion, at the risk of being considered too optimistic in my views, I will say that within the next ten years the local battery magneto telephone instrument, with its associated magneto switch board, will be considered as a rarity in the United States.

MR. CHARLES BRADLEY:—As has been explained here this evening, great improvements have been made in the design and operation of the telephone switchboard since 1880 and also in central office apparatus. It is only, however, in the past ten or twelve years that the planning of installation work has been given much attention, especially from an engineering standpoint. Previous to the advent of

the branch terminal switchboard nearly all work outside of the building of the switchboard proper and the distributing frames, was done by the foreman at the time of installation. In fact, the same man wrote the specifications, went into the shop and superintended the forming of cable, such as they were, and then started on the road to look after the erection of the switchboard. Up to this time switchboard cable was made on the unicolored insulation principle, *i.e.*, in a twenty pair switchboard cable, all the twenty pairs had one red and one white wire. As you can readily understand, this necessitated the testing of one of every pair of wires before soldering them to the multiple jacks or to any other terminal. This, of course, entailed a great loss of time in the erection of the switchboard. The multi-colored insulation scheme was then devised. This consisted of having the insulation of one of each pair of wires of a color different from all the rest; for example, one of a pair blue, of another pair orange, of another pair blue-orange, etc., until the whole combination was effected. Also a regular form was made so that the same colored wire would take the same jack throughout the multiple. Also it was found, since the framework of the sections was made out of iron and more uniform than those of wood, that by careful measurement the cables could be cut and soldered to the multiple jacks in the factory. This plan was tried with great success in one or two installations and thereafter used universally as it meant more accurate work and a great saving of labor on the road.

With the advent of the branch terminal board came the power plant. Instead of the gravity batteries a storage battery was used, necessitating charging machines, a power board and conduit work. This storage battery was used to restore the drops electrically as well as for the transmitters.

As improvements were being made from time to time by different installation men, though each had his own ideas regarding the work and no two installations were made in the same manner, certain of these men were retained in the shop as consultation men and an attempt was made to classify the work and have it done in a uniform manner. More elaborate specifications were prepared, and plans furnished showing the location of the switchboard, power plant, conduit, etc.

When the common battery board was planned this work increased greatly, owing to the number of cable runs, more apparatus and power plants of larger capacity. It was found that by locating exactly each piece of apparatus that the racks for carrying the cables could be designed accurately and built in the shop, conduit plans be prepared and in fact innumerable details that were formerly left to the installer were now figured out by the engineer before the installation actually started. Particular attention was paid to the arrangement and location of apparatus on the switchboard proper, so that the cable work could be done in such a way that all apparatus would be accessi-

ble and easy to maintain. To-day practically all cables are cut and formed from plans made by the engineer and are soldered to their respective terminals or jacks before they leave the factory.

Of course, I have taken but a few examples to illustrate the progress of installation work, but I think it sufficient to show the great improvement made in this class of work in recent years.

(COMMUNICATION AFTER ADJOURNMENT BY SIDNEY HAND BROWNE.)

In his closing remarks, Mr. Lockwood, in his article entitled, "The Evolution of the Telephone Switchboard," refers to the complex organization of the modern relay switchboard and intimates that the next step in its evolution may be along lines which will simplify it rather than in a direction involving a radical departure from its present organization.

A partial simplification has been obtained, resulting in a better "talking circuit" and reduction in first cost and in maintenance. Such simplification consisting of a reduction in the amount of switchboard cable required in wiring the multiple jacks to two-thirds of what is required under the system described; avoiding the use of a shunt to put out the supervisory-lamp; dispensing with the use of the repeating-coil in the cord-circuit as shown, and with the third contact in the multiple-jacks.

In the diagram, Fig. 9 (Lockwood's article), it will be seen that the relay which controls the operation of the supervisory-lamp is placed in series on one side of the talking-circuit, although there is no corresponding impedance in the opposite side of this circuit. And although this relay is of low resistance, it will slightly unbalance the line, and its insertion in this manner should be avoided if possible.

It is also seen that the test-rings of the multiple-jacks are connected by a third wire running the entire length of the switchboard. If this third connection could be avoided, it would simplify matters and be a desirable improvement. By reference to the diagram attached hereto, it will be seen that this has been accomplished, with a consequent saving in switchboard cable, first cost of construction, and reduction in cost of maintenance. By dispensing with this third wire in the multiple-jacks, we have also been able to use a two-conductor cord instead of a cord with three conductors, as shown in Mr. Lockwood's diagram. This reduces the first cost of cords and their maintenance.

It is desirable, if possible, to avoid the use of the repeating-coil in the circuit shown in Mr. Lockwood's diagram, as it is frequently the case that these coils are not properly balanced; and a very slight variation in the size of the core, or inaccurate winding by the manufacture will cause enough unbalancing to interfere with the proper working of the circuit. The use of this repeating-coil has also been avoided in the system described in the drawing attached.

By shunting the supervisory-lamp, as shown in Mr. Lockwoods, diagram, when the telephone is taken from its hook, the flow of currents through these lamps and their shunts continues and causes considerable drain on the batteries.

Figs. 1 and 2 show two telephones connected through a telephone exchange system whose operation is as follows:

The operation of removing the receiver from the hook of the sub-station instrument closes the circuit and energizes the line

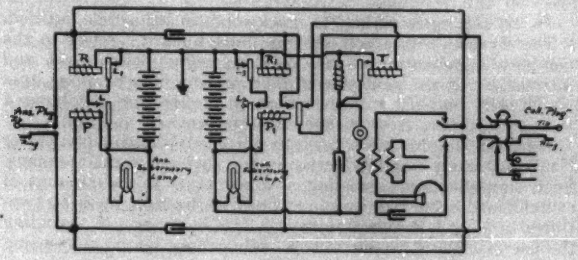

FIG. 1.

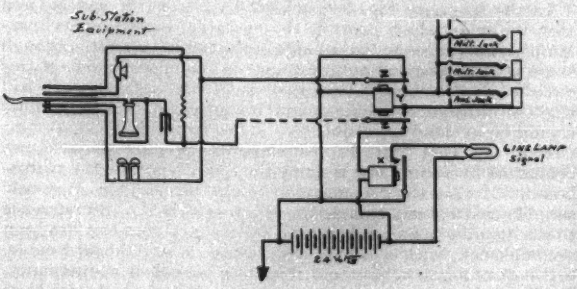

FIG. 2.

signal-relay X in the usual manner. The operator, by inserting the plug in the answering-jack, allows current to flow over the ring of the plug through a relay Y, of high impedence, to the ground; this relay being energized attracts its armature, Z, and disconnects the line signal apparatus, consisting of relay X and lamp, and also "puts current" on the sleeve of the jack, which will give the busy-test through a relay T placed in the operator's circuit. The advantage of this relay controlling the busy-test is that by its use the operator only gets the signal without con-

veying it to the subscriber who has made the call. The insertion of the plug also causes current to flow through relay P, closing the local contact at L, and allows current to flow through the lamp to the local contact at L on relay R to ground. These relays are of low resistance and are placed on each side of the cord-circuit. When the subscriber answers his call by taking the telephone from its hook, it allows the current to pass back over the tip of the cord to relay R to ground and opens the local contact at L, thus cutting out the supervisory-lamp. It will be noticed that there is a straight through circuit from the tip and sleeve of the answering cord to the tip and sleeve of the calling cord with the condensers C_1 and C_2, inserted. These condensers permit the flow of voice-currents and prevent the steady flow of current from the battery, which simply supplies current for the sub-station transmitter.

The system described eliminates the features which we stated above we did not think were desirable and as shown in diagram, Mr. Lockwood's article. It is true we have introduced the relays R and P and R_1 and P_1, but these relays are wound to a high impedance and are not connected directly in the talking-circuit, but are bridged across it. The circuit is perfectly balanced, which is not true of the circuit as shown in Mr. Lockwood's diagram, and instead of shunting the lamp we open the lamp circuit and save the drain on our batteries.

To anyone who is familiar with the amount of wire necessary in a large multiple switchboard and the consequent greatly increased cost of manufacture, it will be apparent that immense saving can be made by the elimination of one-third of the amount of multiple switchboard cables necessary in the system described by Mr. Lockwood, by the use of two contact jack instead of three contact, by the use of two conductor cords instead of three conductor, and in addition to these savings in first cost and maintenance we obtain a much more direct and better talking circuit.

Upon motion of Prof. Kintner, a unanimous vote of thanks was extended to Mr. Snyder for his exhibition of the Arcophone.

J. S. PECK,
Secretary.

DISCUSSION AT UNIVERSITY OF ILLINOIS, FEB. 7, 1903.

Prof. W. H. Williams in the Chair.

Three members of the INSTITUTE, Prof. W. H. Williams, Mr. H. C. Marble and Prof. Morgan Brooks and twelve University students were present. The papers by Mr. Thomas D. Lockwood and Mr. William J. Hammer were presented in abstract and then discussed.

In regard to Mr. Hammer's paper, Prof. Williams said that intricate automatic machinery required expert attention, instancing the necessity for adjustment and repairs upon linotype machines, and suggesting that the saving in operators' salaries might be required for the pay of expert mechanics. Prof.

Brooks thought that the 10 per cent. depreciation claimed by Mr. Hammer as ample for the automatic switchboard would prove inadequate, especially in view of the probable changes in details of construction to be expected. The bookkeeper's 10 per cent. depreciation becomes but 9 per cent. the second year, and about 8 per cent. the third year, hence at the end of ten years the entire first cost has by no means been charged off. He asked if any switchboard built in 1893 would now be worth 35 per cent. of its original cost, as it would have to be on the basis of a 10 per cent. yearly depreciation deduction.

MORGAN BROOKS,
Secretary.

Discussion at Chicago, December 30, 1903.

Local Honorary Secretary R. H. Pierce in the Chair.

The papers discussed were: "Some Brake Tests and Deductions Therefrom," by Mr. J. D. Keiley, and "Railroad Car Braking," by R. A. Parke. The first paper was read by Mr. B. J. Arnold, and the second by Mr. T. P. Gaylord.

At the conclusion of the reading of Mr. Keiley's paper, Mr. Arnold said: I think this is a very interesting paper, but it is more useful as a matter of reference than for discussion, unless one is a little more familiar with the conditions under which the author worked.

At the conclusion of the reading of Mr. Parke's paper, Mr. Gaylord said: Any method of electric braking requires that special attention should be given to the capacity of the motors applied to the car. I know of a number of cases of trouble from motors installed in cars using electric brakes, due to the fact that the motors were furnished on the supposition that they would have their usual relaxation from work during the periods of braking and stopping; but with the use of electric brakes the motors do not derive the same advantages in cooling off. In some instances this will make quite a difference in the size of the equipment to be used.

Mr. J. R. Cravath:—The question of rapid-service stop-braking on interurban equipments has not, apparently, been a very serious one on most of the interurban roads that have heretofore been installed; at the present time the matter is being agitated, and I know of at least one road where the ordinary service stops on the contemplated schedules will call for something that is of the nature of an emergency stop. Then comes the question of getting the same kind of performance out of an ordinary straight air-brake that you get out of a Westinghouse automatic high-speed brake. Of course, most interurban cars are equipped with straight air on account of its simplicity, and the greater ease with which the motorman can handle it. I believe that on the road which I have in mind there was some intention of accomplishing the same results as with the Westinghouse automatic high-speed brakes, by educating the motorman to start in with a very heavy brake application at the higher speeds, decreasing it as the speed fell off. This will require judgment on the part of the motorman regarding the pressure to be used at the first application, and the rapidity with which it should be decreased. However, a motorman with a straight air-brake, such as is used on interurban cars, should always use judgment, for the full storage tank pressure generally carried is sufficient to slide the wheels.

There is another matter closely related to brakes and braking problems which has not been previously referred to to-night. Some of us have recently seen apparatus that is being exploited for increasing the traction between wheel and rail by magnetism.

Some of the tests seem to be very promising. Of course, if it is possible, with a reasonable expenditure of energy, greatly to increase our coefficient of friction between wheel and rail, it has a very important bearing on braking, especially with a slippery rail.

MR. PIERCE:—Have you any data regarding the supposed increase in the coefficient of friction obtained by this means.

MR. CRAVATH:—I believe that the people who are exploiting this device cite tests on a 15-ton motor car at Seattle, on which it was claimed that with an expenditure of 2½ h.p. in electrical energy the tractive effort, before the wheels began to slip, was increased 350 per cent. One peculiar thing about it is that the traction does not fall off in the same ratio after the wheels begin to slip, as it would if the magnetic device were not in operation.

MR. PIERCE:—The wear on the wheels would be correspondingly bad, I suppose.

MR. GAYLORD:—Do you know whether any experiments have been made as to the effect on the bearings?

MR. CRAVATH:—No; I do not know anything about that.

MR. ARNOLD:—If I recall the matter correctly, Mr. Ries, of Baltimore, discussed that thing pretty thoroughly about ten years ago. He got up some kind of device similar to this. In fact, I do not see anything very different in principle between Mr. Ries' scheme and the scheme just referred to. He simply passed a current through the wheel and rail and back through the machine, causing magnetic adhesion between the wheel and rail. That scheme has not revolutionized anything yet, and I think the matter was dropped. This device referred to to-night may be a little different, but the principle seems to be the same.

MR. PIERCE:—I also remember some experiments having been made some time ago. I do not know that they are the same ones as those referred to by Mr. Arnold; but there was a claim made that a current passing into the track of an ordinary system such as is in common use, caused a certain amount of adhesion between the wheels and the rails. The current passing through the wheel would not magnetize it. Did he have a winding, Mr. Arnold?

MR. ARNOLD:—I do not recall the facts very clearly, but I remember he had us somewhat excited; however, it did not amount to anything. I know he passed a current through the wheel and rail. How he brought it back I do not know, but he claimed an increase of friction between the wheel and rail. But I think the amount of energy spent to do this, and the maintenance, will more than offset its advantages.

MR. CLARK:—I do not know whether any of the gentlemen here have seen this device or not. Some models of it have been on exhibition in Chicago in the Rialto Building. It certainly seems very effective. We watched the car climb a grade that it couldn't possibly have climbed unless aided by that device. When you take hold of the car you can hardly hold it back. I do not know whether the device is still on exhibition or not.

Their idea is to put them on locomotives, and when they encounter a steep grade, to apply the magnetic circuit.

MR. PIERCE:—I have not seen this device, but I received a printed invitation to examine it; however, after having examined a full line of similar articles, I thought I would not take time to look at this one, and sent one of my assistants instead. He came back very enthusiastic about it.

MR. CRAVATH:—Of course the efficiency of any device of that kind depends a good deal on the length of the magnetic circuit.

MR. ARNOLD:—There is no doubt but that it will make the wheel stick to the rail better than if there were no current passing through; the question is, however, how much it will cost you to get the device and how much you will gain by it.

MR. CLARK:—That is a matter of dollars and cents, but when you consider the question of the technical interest, there is no doubt that in turning on the magnetic circuit, you are increasing the traction considerably. That little car could not go up the hill without that device, and with the device it climbed the hill very easily and was able to pull a considerable additional load.

MR. EUGENE B. CLARK:—One point of interest that has occurred to me in connection with the magnetic track braking device, mentioned in the latter part of Mr. Parke's paper, and which I was discussing with Mr. Gaylord just before the meeting was called to order, was the question of how much power is supplied by the motors when they are acting as generators. Mr. Gaylord told me it is a very small amount. I might mention an instance that recently came to my attention. The problem of braking the trolley of an ore-handling machine was before us. The trolley weighed about 140,000 pounds and traveled about 1,000 feet a minute across the bridge of a crane about 100 feet in the air. The bridge was about 500 feet long. We took every possible precaution to produce the most effective braking we could devise, we used air brakes and provided the motor brake, consisting of the brake controller, which converts the motors into generators. We also used a hand brake, and besides that, at the ends, a buffer device. We considered that the most effective part of the braking was that done by the motors and that that part which was due to the effect of the disc, or whatever part might be supplied in place of the disc, was of comparatively small importance. Acting upon that supposition, we did not provide anything except straight resistance in the motors; therefore, we simply converted the motors into generators and loaded them to stop the motion of the car. That was very effective—in fact, too effective. It would not take hold until a certain point, and when it did take hold it did so vigorously. One disastrous result which we thought was due to this cause was the breaking of the axles. We designed an axle that appeared to be strong enough, but we had to enlarge it, and then enlarge it again, and even then the axles would break. Now, I would like to know if it is a fact that the same experience has been met with before in braking street cars; do the axles break?

MR. B. J. ARNOLD:—I think the chief objection that has been brought against electric brakes that act upon the clutch principle is the increased size that the motors must have in order to stand up under the work, since they are working all the time, as Mr. Pierce has pointed out and as others here have mentioned. I have never heard of the axles breaking from that cause, although they might have done so, but of course axles break for other reasons. In hilly countries axles are more liable to break than they are in flat countries. It might be that the axles break more on that account than from the magnetic brake.

MR. T. P. GAYLORD:—I am somewhat familiar with the situation in Pittsburg, where conditions with respect to grades are rather severe. As Mr. Arnold has said, the breaking of axles is largely due to mechanical conditions rather than conditions of load on the motor acting as a generator. As to the amount of energy developed in a motor, I understand that in the Newell brake system the energy derived from the motor acting as a generator is just about sufficient to compensate for the energy stored in the revolving elements of the motors and the truck wheels. In other systems I think, perhaps, the amount of energy taken from the motor is considerably more.

MR. CLARK:—It is to be noted in the case I mentioned, that we worked on the assumption that the principal part of the braking was due to the load on the motors. It is not at all unlikely that we were wrong in that assumption. Of course, under such conditions as we were operating, all of the work was done in the motors, and therefore the load on the motors was considerable. There was no braking anywhere else.

MR. PIERCE:—In the use of this system where the current generated in the motors acts on the magnetic brake, how much would that increase the size of the equipment, in ordinary practice?

MR. GAYLORD:—It is difficult to make any general statement; it would vary with every different installation, depending on the frequency of stops.

MR. CLARK:—I can say that we found no difference, as far as we could determine, in the temperature of the motor, whether we were using the motor brakes or not.

MR. PIERCE:—Was the motor acting at a low voltage during the time it was working on the brakes?

MR. CLARK:—Oh, yes. There was probably considerable current, but only for short periods of time. We had an air brake which could be used.

MR PIERCE:—Are you referring to this particular case?

MR. CLARK:—Yes; the particular case of the ore-handling machine. It seems to me that is of interest as a bit of evidence showing that one cannot depend upon the belief that I think is quite prevalent among those who use this method of braking, that the principal part of the braking is in the motor.

MR. PIERCE:—I notice in the paper describing the air brakes,

attention was called to the fact that as these brakes were originally installed, the valves acted slowly, so that the brakes were set on the last car considerably later than on the first car; but in the quick-stop, automatic arrangement here described the action is very much quicker.

I notice it said in the paper that the power to be given these valves was transmitted as rapidly as sound. It occurred to me, in reading this paper, that that was not a very great speed at which to transmit this power; that would only be equivalent to about 1,100 feet a second. On a long train, going at a very high rate of speed, the time required to transmit the signal for down-brakes would be from one-half second to one second between the action of the valves on the front car and the last car, and in extreme cases there might be a difference in time which would correspond to a car length in distance. I think it was in 1886 that some tests were made for the application of electricity to operate the air valves, so they were operated simultaneously on all cars. These were tests that the Westinghouse people participated in, and I believe they soon afterwards became owners of the patents. I think that is the last I have heard of the matter. I do not know whether the Westinghouse Company has ever used that device or not. I remember there was a lever by which the electricity was thrown into a device operating the valves, and they all operated simultaneously. The electricity was provided by storage battery. I presume the gentleman who wrote this paper was familiar with what was done at that time, and what has been done since. I should like to know if any one here is familiar with that subject. It seems to me we should get the same result as we do with the multiple-unit system, where we not only accelerate on all the cars, but the acceleration starts at the same instant. If we could start the retardation on all cars at the same time, it would be of great advantage.

MR. ARNOLD:—I was a guest of the Westinghouse Air Brake Company during the time those tests were made. A good many railroad men were invited at that time to witness those experimental air brake tests. It was in 1887. They made some tests between St. Paul and Minneapolis on the Northern Pacific road, and made several runs at various speeds and various applications; then, after making these runs, they showed how rapidly they could stop the train, and how quickly they could pile us up in the ends of the car, if they did not use the quick-acting brake. They finally stopped the train and let us stand along the track beside the train, near the last cars. Then we watched the locomotive, the whistle was pulled the instant they applied the brakes and we could see the steam come out of the locomotive. The brakes on the rear cars would be applied before the sound from the whistle reached us. It showed that the brakes acted more rapidly than sound would travel. I saw that experiment several times.

It is a fact that about that time, or soon after, this electrical

brake came out, and it was acquired by the Westinghouse Company, but for some reason they have not developed it. But I understand the fact is, the electrical device which Mr. Pierce spoke of did the work more satisfactorily than the air, but it introduced additional complications that were not really necessary, and because air did the work practically well enough, they have continued to use air.

THE ENGINEER OF THE TWENTIETH CENTURY.

BY CHARLES F. SCOTT.

Response to a toast at the Twenty-fifth Anniversary of the Engineers' Club of Philadelphia, held at Union League, Saturday, December 6, 1902. The invitation to be present at the Anniversary was extended to Mr. Scott as President of the Engineers' Society of Western Pennsylvania and as President of the AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS.

GENTLEMEN:—It is significant that the response to this toast is assigned to the representative of the Engineers' Society of Western Pennsylvania. This society represents the engineers of Pittsburg, the city above all others pre-eminent in its industrial and engineering works in the country which is assuming the industrial supremacy of the world. The products of Pittsburg owe their inception to the inventions and designs of the engineer; under his supervision they are manufactured; and in turn they become the materials which other engineers employ in the construction of buildings, railroads and power plants throughout the whole world. This is the age of steel; Pittsburg furnishes the steel. This is the age of electricity; she produces the largest dynamos. The tonnage of Pittsburg's railways far exceeds that of New York city. The tonnage of the Pittsburg harbor, notwithstanding shallow bottoms and low bridges approximates that of the New York harbor. Industrial Pittsburg! of the engineer! by the engineer! for the engineer!—typical of the present, significant of the future! Do you ask me to portray that future? I ask you to look back fifty years to the time when the first railroad bridge across the Allegheny built against the protest of hack drivers and sympathetic citizens, brought together the track from Ohio and the track to Philadelphia; it brought them together, but it did not join them; for the State legislature had ordained that the gauges of the tracks should be different, in order to prevent domestic cars from wandering too far from home. Compare conditions then with those now. Note what the

engineer has done since some of those present reached middle life. Who will venture to predict what we young men may see before we become old? It is with pride that I see how my own city—Smoky City of the Keystone State, the city of engineers and of industry—is growing in influence. A week ago a Philadelphia paper quoted a multi-millionaire thus: "Pittsburg instead of Wall Street must be considered hereafter as the potent factor in the continuation of our national prosperity." When money rates go up in Wall Street and wage rates go up in Pittsburg simultaneously, it is the industrial thermometer which most truly indicates the real prosperity. ENTER ENGINEER; EXIT SPECULATOR.

It is significant also that the response to this toast is assigned to the representative of the AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS. This organization represents the electrical engineers of America—the country above all others pre-eminent in electrical activity—at a time when its applications are making this the age of electricity. For a retrospect of general engineering we appeal to the memory of men past middle life; but the electrical awakening is within the easy memory of us all.

Electrical work is seldom independent. It does not stand alone, complete in itself. Electricity is usually an instrument, a means to an end. It is not energy derived at first hand from electricity which enables the car to move and the crane to lift a weight. It is power derived from the engine, which happily can be transmitted by electric wires better than by shafts or ropes or belts. It is because electricity is primarily an agent, a means, that its applications have been so diversified, so extensive, and so far-reaching in their effects.

The telegraph, the cable, the telephone have had a profound effect upon political, commercial and social affairs. The applications of electricity bring the evolution of new methods as well as the revolution of old ones. It is a new instrument which has given to the whole world a new method of doing things.

The electrical engineer follows the new gospel, the gospel of service. His mission is helpfulness. Through his aid the mining engineer lights his mine, drives his fans and pumps and drills, and conveys his product. Through his aid the mechanical engineer has modernized the machine shop by the electric crane and by motor-driven tools, which increase output and reduce cost. Through his aid the railway engineer has replaced the horse-car by the people's automobile, which for a few cents will

carry anybody from city to suburb more quickly than it was possible by any means at the command of even the millionaire a dozen years ago, and that, too, with the added comforts of warmth and light. Through his aid a new realm is opened to the chemist in the field of electrochemistry. Through his aid the engineer of plant life, the farmer of the west, transforms the desert into a garden by motor-driven pumps and the distant water power. Through his aid the engineer of human life is given a new sight to penetrate the living body and a new stimulus to excite the inactive muscle. Through his aid the luxuries of yesterday have become the necessities of to-day, and the impossible has become the commonplace.

The great discovery of the nineteenth century was *cooperation*, the effectiveness of concentration, the efficiency of largeness. Compare the old days of the hand loom in the home, of the shoemaker at his bench, of the individual oil well and coal mine, of the small railroad and of the small factory—compare these with modern methods, pregnant as they are with unbounded possibilities—possibilities of good and possibilities of evil; of good, because the engineer has provided the means for doing the world's work far more efficiently; of evil, because the social, the industrial, the commercial systems have not kept pace with the advance made by the engineer, but are still tainted with injustice and selfishness.

The tendencies of the nineteenth century projected into the future, reveal in dim outlines at least, the engineer of the twentieth century. He is to deal with large affairs in a large way. He is to be closely related to every department of modern life. He is to become a chief factor in adjusting and operating the intricate mechanism of a new civilization. He is to advance to administrative positions for which his knowledge and his training peculiarly fit him. Note present examples. At the head of the Pennsylvania Railroad, directing its vast affairs in the present and planning to meet the demands of the future, is an engineer surrounded by engineers—President Cassatt. At the head of the interests with which I am connected is a man, successful as organizer and manager and financier, a genius in his foresight, but first of all an engineer, George Westinghouse. Sound judgment, breadth of view, integrity of character, the ability to understand and to control men as well as matter, and to direct human forces as well as physical forces, are essential to the engineer of the future. A recent event which has aided in bringing America to

pre-eminence is the victory of our navy. A naval battle is a contest between fighting machines, and these are the products of the engineer. All honor, then, to the engineer, so fittingly represented here to-night by Admiral Melville.

Besides their new relations to others, there will be new relations of engineers among themselves. All that I have said so far emphasizes what we all know, namely, that the several branches of engineering are intimately interdependent and correlated. Take a single instance of large work, the extension of the Pennsylvania Railroad into New York City—the tunnels under the Hudson and East rivers, the terminal facilities and the electrical equipment—and endeavor to name an important branch of engineering which is not essential to this undertaking. The work of the future demands coöperation, not clanishness—unity, not jealousy. Engineers must be specialists, therefore they must work together. The several branches of the profession have their individual interests; they have a larger common interest. As we marvel at what the engineer has done, as we attempt to picture what he may accomplish, do we realize the far-reaching responsibilities which confront us? Shall we rise to meet them? We gave to the world the steam engine, the steam vessel, the railroad, the telegraph and the cable, machinery, industrial processes, the electrical central station—the fundamental requisites which underlie coöperation. Is it not time that we apply to ourselves the great lesson of the last century? What organization stands before the world as reprensetative of the engineering profession? In what way do engineers present themselves to other professions? A noted lawyer recently addressed the annual banquet of a local engineers society containing members of national and international reputation. His remarks were based upon the idea that all engineers were co-ordinate with a common chainman, and they would have been positively insulting but for his air of blissful ignorance. A few years ago a gentleman of eminence in addressing the American Society of Mechanical Engineers, advised its members not to join in a machinists' strike! Has the engineer been accorded the recognition and the reward which are his due? In what way do engineers coöperate to advance their own profession by mutual helpfulness and by undertaking measures which advance the efficiency and the usefulness of engineering work? There are national engineering organizations of various kinds—the civil engineers, the mining engineers, the mechanical engineers, the electrical engin-

eers, the architects, the naval architects and marine engineers, the engineers in the army and the navy and there are the chemists the electrochemists and others. In general, each knows that other societies exist, and they are mutually respectful, but there is some suspicion here and there that the others are a little too exclusive or that they are a bit jealous. These are the murmurings of littleness, not of largeness.

The several engineering professions, like the constituent States, have their representative bodies, their legislatures, but why should there not be an engineering congress as well? Why not a national representative body, to stand for the profession of engineering as a whole, to promote a harmonious coöperation which will strengthen each and elevate all?

An incident of the past year is an auspicious omen. Four great societies have coöperated; they have taken a step which will bring recognition to the deserving individual and credit to the engineering profession. They have founded a medal; and at a recent magnificent dinner they have announced the award of the first John Fritz medal to the venerable man who has just spoken, John Fritz himself. But not less significant than even the medal is the discovery that the societies can work together, and that by doing so they can accomplish worthy ends.

In the vision of the future may we not discern a reflection of the John Fritz medal in the larger life of the twentieth century engineer? Methinks I see in that reflection the outlines of a magnificent building, the Capitol of American Engineering. Into this home, situated in the metropolis of the nation, are gathered the great engineering societies from their scattered lodgings. Here is a great technical library; here are ample assembly halls and comfortable parlors; here are the headquarters of a score of lessor societies restricted in their scope but affiliated in their work. I see all over the country innumerable local societies and engineering clubs, no longer isolated but joined together into one great combination. I see them affiliated with the national bodies of the several professions—sometimes as local chapters—altogether constituting one great union. There is individual freedom but general coöperation. Representing all the engineering professions and supported by the great union of the national engineering societies, I see an engineering congress giving to engineers a rank consistent with the importance of their work, and increasing the efficiency of the inter-relations among its members. An eminent body, it is powerful in advancing the

common interests of engineers, and it represents the engineering profession in its relation to other professions, to pure science, to education, to legislation, to public improvements and to the general welfare.

Years ago engineers were individuals of trivial consequence compared with men in the learned professions. Now, they, too, form a profession of recognized importance. But as yet the national societies of this profession, which has made the nineteenth century an era in the world's history, which has provided the means for the production of unmeasured wealth, and which promises yet greater things for the future, have not even adequate homes of their own. Within the present week the Society of Mechanical Engineers, which has a little house of its own, found it so very little that it was forced to hold its meetings in a large room in a nearby tavern, although there were present men through whose work hundreds of millions have been added to the wealth of this country, and their present efforts are to increase the efficiency of the future. Is this right? Is it just?

But may not the fault lie somewhat with the engineers themselves? Have they fully recognized their own strength and importance? Have they shown a disposition to act together, to do large work in a large way? Have they given promise that they would use the enlarged facilities in such a way as to increase the efficiency of engineering work?

The men who are mastering the powers of nature will yet rise in the strength of united effort to meet the increasing responsibilities of the coming years. For it is theirs to build the foundation of the new civilization; it is theirs to establish that material prosperity which is the underlying condition of broader, higher and fuller life.

The end of engineering is usefulness; the characteristic of America is activity; the modern method is coöperation. As engineers of the twentieth century, let us be useful; let us be active; let us coöperate.

BOOKS AND PAMPHLETS

IN WHEELER GIFT

PUBLISHED PRIOR TO 1826.

*Titles preceded by * are those of books recently added by Dr. Wheeler to the collection.*

Abercorn, J. Hamilton, 6th earl. Calculations and tables relating to the attractive virtue of loadstones... 8°. *n. p.*, 1729

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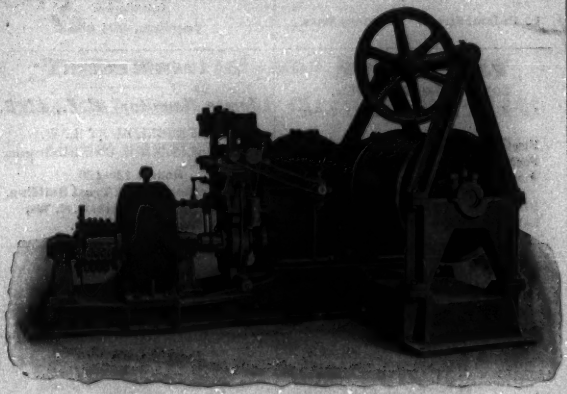

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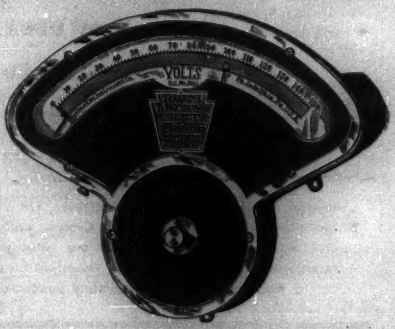

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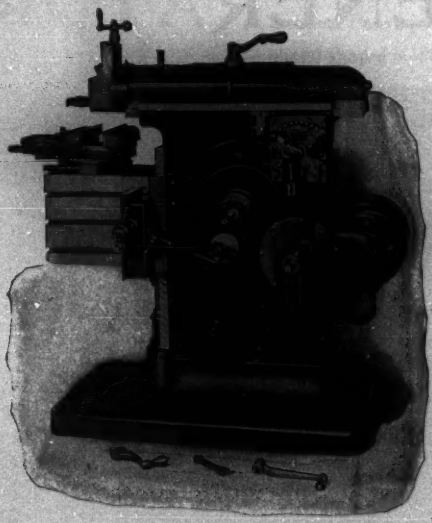

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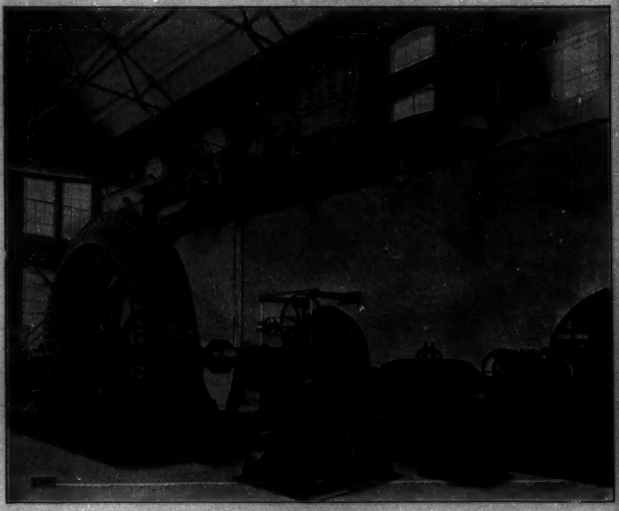

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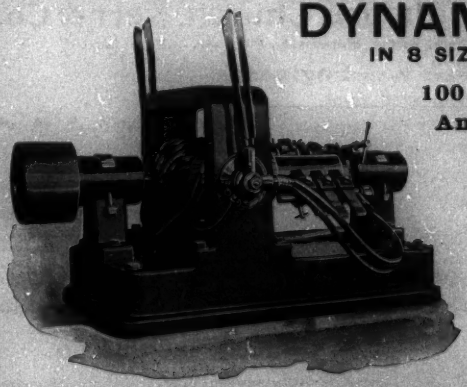

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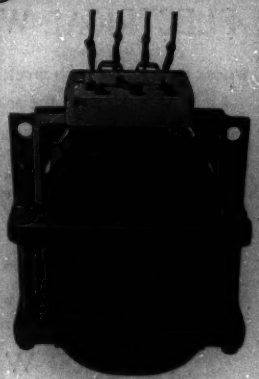

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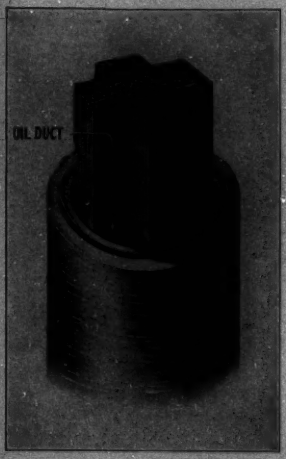

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